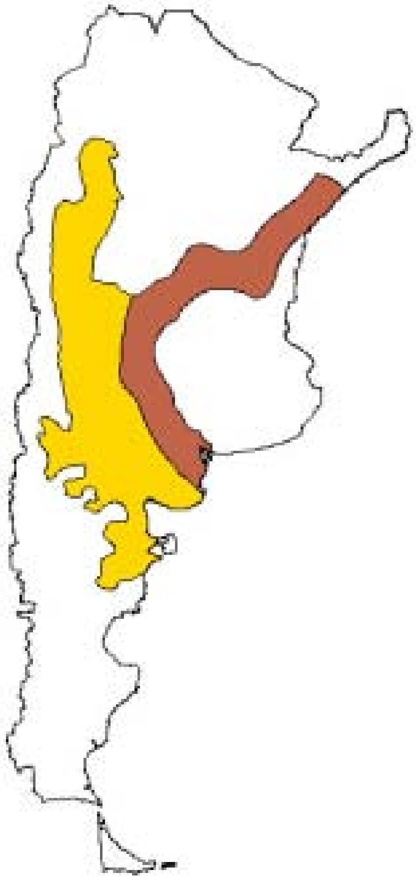
Forestry Department
Food and Agriculture Organization of the United Nations

FRA 2000

FOREST COVER ASSESSMENT IN THE ARGENTINEAN REGIONS OF MONTE AND ESPINAL



Rome, August 2001

The Forest Resources Assessment Programme

Forests are crucial for the well-being of humanity. They provide foundations for life on earth through ecological functions, by regulating the climate and water resources, and by serving as habitats for plants and animals. Forests also furnish a wide range of essential goods such as wood, food, fodder and medicines, in addition to opportunities for recreation, spiritual renewal and other services.

Today, forests are under pressure from expanding human populations, which frequently leads to the conversion or degradation of forests into unsustainable forms of land use. When forests are lost or severely degraded, their capacity to function as regulators of the environment is also lost, increasing flood and erosion hazards, reducing soil fertility, and contributing to the loss of plant and animal life. As a result, the sustainable provision of goods and services from forests is jeopardized.

FAO, at the request of the member nations and the world community, regularly monitors the world's forests through the Forest Resources Assessment Programme. The next report, the Global Forest Resources Assessment 2000 (FRA 2000), will review the forest situation by the end of the millennium. FRA 2000 will include country-level information based on existing forest inventory data, regional investigations of land-cover change processes, and a number of global studies focusing on the interaction between people and forests. The FRA 2000 report will be made public and distributed on the World Wide Web in the year 2000.

The Forest Resources Assessment Programme is organized under the Forest Resources Division (FOR) at FAO headquarters in Rome. Contact persons are:

Robert Davis	FRA Programme Coordinator	robert.davis@fao.org
Peter Holmgren	FRA Project Director	peter.holmgren@fao.org

or use the e-mail address: fra@fao.org

Table of contents

Paper drafted by: Dan Altrell, FAO-FRA Programme
Editorial production: Patrizia Pugliese, FAO-FRA Programme

Abbreviations

AVHRR	Advanced Very High Resolution Radiometer
BIRF	Banco Internacional de Reconstrucción y Fomento
BSQ	Band Sequential format
CAC	Canadian-Argentinean Inventory Consortium
ESRI	Environmental Systems Research Institute
FAO	Food and Agricultural Organization of the United Nations
FRA	Forest Resources Assessment
GIS	Geographic Information System
GPS	Global Positioning System
IFONA	Instituto Forestal Nacional (Argentina)
IR	Infra Red
Landsat TM	Landsat Thematic Mapper (scan mirror spectrometer)
NDVI	Normalized Difference of Vegetation Index
RGB	Red, green, blue
SAGPyA	Secretaría de Agricultura, Ganadería, Pesca y Alimentación
SDSyPA	Secretaría de Desarrollo Sustenable y Política Ambiental (Secretariat for Sustainable Development and Environmental Politics - after year 2000)
SRNyDS	Secretaría de Recursos Naturales y Desarrollo Sustentable (Secretariat for Sustainable Development and Environmental Politics - before year 2000)
TIFF	Tagged Image File Format
UTM	Universal Transverse Mercator System
WGS	World Geodetic System

Summary

This study is a forest cover assessment carried out in the phytogeographical regions of *Monte* and *Espinal* in Argentina, in the year 2000. The objective with the study was to urge on the collection of forest cover data for FRA 2000 since the ongoing Argentinean national forest inventory not would be able to present recent data for these regions in time for the FRA 2000 global analysis. The assessment was carried out through a visual forest cover interpretation in a sample of eleven satellite scenes (Landsat TM) combined by a field visit to make a ground truthing of the visual interpretation. The result of he study presents, for the region of *Monte*, a native forest cover of about 36 000 ha and a forest plantation area of less than 400 ha, and for the region of *Espinal* a native forest cover of about 530 000 ha and a forest plantation area of 53 000 ha. The estimations presented for native forest cover in both regions of Monte and Espinal are significantly lower than earlier figures presented by the Argentinean authorities indicating its need of revision.

Resumen

El presente estudio corresponde a un levantamiento sobre la cobertura forestal en las regiones fitogeográficas de *Monte* y *Espinal* de Argentina ejecutado en el año 2000. El objetivo del estudio fue adelantar la recolección de datos forestales para el FRA 2000, debido a que en el inventario nacional forestal, que se está llevando a cabo, los datos sobre estas regiones no estarán disponibles para el análisis global del FRA 2000. El levantamiento se ejecutó a través de una interpretación visual de la cobertura forestal en una muestra de once imágenes satelitales (Landsat TM), en combinación con visitas de campo para verificar la interpretación visual. El resultado del estudio presenta para la región de *Monte* una extensión de bosques nativos alrededor de 36 000 has y una superficie de plantaciones forestales de menos de 400 has; y para la región de *Espinal* una extensión de bosques nativos alrededor de 530 000 y una superficie de plantaciones forestales de 53 000 has. Las estimaciones presentadas para la cobertura de los bosques nativos en ambas regiones de Monte y Espinal son mucho más bajas que las cifras presentadas anteriormente por las autoridades argentinas, indicando la necesidad de revisión de las mismas.

1 Introduction

A priority activity for FAO in forestry is the Regional and Global Forest Resources Assessment, FRA. Available data on forest cover, types of forests and other data on the state of forests are collected on country basis, or preferably on sub national basis, to be components of Regional and Global Analysis of the world forests.

For the last Regional and Global FRA the source for the Argentinean forest statistics, IFONA 1987, originated from 1986 and presented a native forest cover of 34.530.000 ha and from this source FRA estimated a native forests coverage of 33.394.500 ha in 1995. The forest statistics in IFONA 1987 were based on various partial forest inventories from different years using different terms and definitions. These inventory results were compiled without any distinction regarding terms and definitions used in the different inventories, meaning that the source for this reason and others is of low precision and therefore not reliable to be used directly in the FRA 2000. It was decided that for the coming FRA (2000) a new effort should be made to achieve more updated data to improve the quality of the new regional and global FRA analysis.

1.1 The state of the Argentinean national forest statistics

Current Argentinean native forest statistics (Appendix 1) are based on estimations made in 1989 from provincial inventories and reports, satellite interpretations and a preliminary appraisal on the national forests (Montenegro, 2000). Updated forest statistics will be presented through an ongoing national forest inventory for native forests and protected areas, but data from this inventory are still not available except for the region of *Misiones* (SDSyPA, 2000).

Concerning forest plantations, there is also an ongoing national inventory, but data available at the Ministry of Agriculture, Livestock, Fishery and Food regarding plantation areas are based on provincial information presented by planted tree species and province. The plantation statistics are given annually from 1992 until 1998 and the total area planted is presented by province for the actual year of estimation, which varies for the different provinces (Corinaldesi 1998, Fernández 1999, Maradei 1999, SAGPyA, 1998).

1.2 National Forest Inventories

Two national forest inventory projects have recently been carried out in Argentina: the Forestry Development Project for plantations, and the Native Forests and Protected Areas Project. Both projects were executed by the forest inventory consortium, Consultora Forestal Argentino Canadiense, CAC, consisting of the companies Aeroterra S.A., Simons and Tecsult. The work of the consortium was supervised by the Forestry Divisions at the Ministries of Agriculture and Social Action, respectively. The inventory of forest plantations started at the end of 1997, while the native forest inventory in April 1998. The two projects, finalized by July 2000 and March 2001, are the first national forest inventories ever carried out in Argentina.

As a preparation for the national inventories the extension of the phytogeographical regions of Argentina was revised by the Native Forest Division and the wooded regions specified (Figure 1). The inventories are carried out in different stages according to the climate conditions in the different regions. The regions were assessed and inventoried according to a certain schedule and therefore the results of the inventories were gradually becoming available.

According to time schedule presented in November 1999 the Inventory Consortium CAC, results would be available for the *Selva Misionera* in March 2000 and for the *Bosques Andino Patagónicos* in June 2000. Data covering the *Selva Tucumano Boliviana* and the *Parque Chaqueño* would be available by December 2000 and finally data for the regions of *Monte* and *Espinal* by September 2000 respectively March 2001. The Regions of *Monte* and *Espinal* are characterized by scarce, dry to semidry forest formations with low productivity.

Since the two phytogeographical regions of *Monte* and *Espinal* (see Figure 2) would not be covered by the national native forest inventory until the end of year 2000 respectively at the beginning of year 2001 an effort was made to co-operate with the Consortium CAC to urge on the data collection. An advance that was desired to be able to present recent and complete data on the forest cover for the whole of Argentina in the global FRA 2000 analysis.

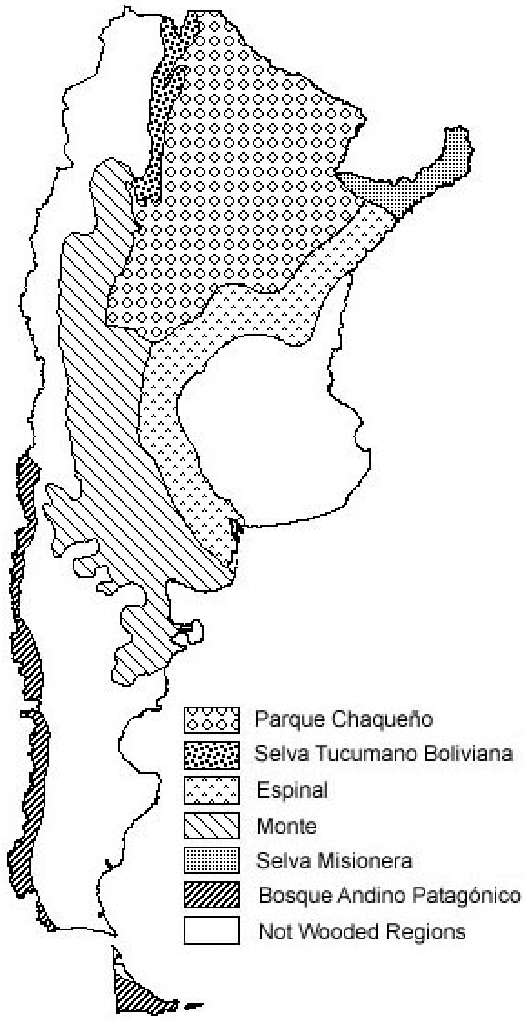


Figure 1 Phytogeographical regions of Argentina classified according to the National Inventory of Native Forests.

1.3 Sample in the regions of Monte and Espinal to accelerate the achievement of forest cover data

Due to the applied sampling design, it was not possible for the inventory consortium to present data in advance over these two regions without employing extra personal working parallel with scheduled activities. For FRA 2000 it was not feasible to finance this external extra cost, knowing that the regions of *Monte* and *Espinal* are the two forest regions of less importance in Argentina. Therefore FRA initiated a study based on visual interpretation of forest cover in a sample of satellite images over the regions of *Monte* and *Espinal* to be completed by ground-truthing verifying the visual interpretation.

2 Methods

In order to advance an estimation of the native forest cover in the regions *Monte* and *Espinal* a sample of twelve Landsat TM satellite scenes[1] was sampled, six in each region. Due to high heterogeneity within the region of *Espinal* the sample was selected through stratified random sampling, dividing this region into three sub regions (Figure 2); *Espinal-Ñandubay*, *Espinal-Algarrobal* and *Espinal-Caldén*, with two scenes corresponding to each one of them.

Tables with paths and rows for those satellite scenes with a theoretical coverage within the regions/subregions of *Monte* and *Espinal* were created and the scenes were numbered for the sampling procedure, Table 1a-d.

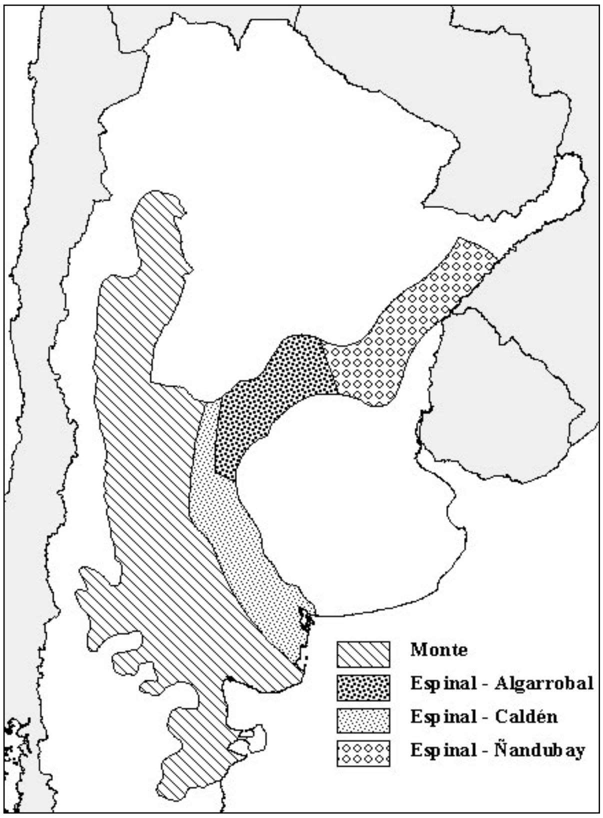


Figure 2. The phytogeographical regions of *Monte* and *Espinal*, showing the subregions of *Algarrobal*, *Caldén* and *Ñandubay*.

Table 1a-d. Spatial distribution and enumeration of Landsat TM satellite scenes in the regions/subregions of *Monte* and *Espinal* presented by the paths and rows.

	MONTE							
	P233	P232	P231	P230	P229	P228	P227	P226
R078		3	12					
R079		4	13					
R080		5	14					
R081	1	6	15					
R082	2	7	16					
R083		8	17					
R084		9	18	22				
R085		10	19	23				
R086		11	20	24				
R087			21	25	27	30		
R088				26	28	31	34	
R089					29	32	35	36
R090						33		

	ESPINAL Caldén					
	P230	P229	P228	P227	P226	P225
R078						
R079						
R080						
R081						
R082						
R083	101					
R084	102	104				
R085	103	105	108			
R086		106	109			
R087		107	110	111		
R088					112	
R089						
R090						

	ESPINAL Algarrobal					
	P230	P229	P228	P227	P226	P225
R078						
R079						
R080						
R081						
R082			203	205		
R083		201	204			
R084		202				
R085						
R086						
R087						
R088						
R089						
R090						

	ESPINAL Ñandubay					
	P230	P229	P228	P227	P226	P225
R078						
R079						306
R080					303	307
R081				301	304	308
R082				302	305	309
R083						
R084						
R085						
R086						
R087						
R088						
R089						
R090						

[1] Scenes from the satellite Landsat 5 with the scan mirror spectrometer Thematic Mapper, TM.

The MS Excel random function **RAND()*(b-a)+a,** were **a** is the first value in the population and **b** the last, was applied in each cell in a table designed for selecting the sample of satellite scene positions, (Table 2). The final sample of satellite scene positions is shown in Table 2.

Table 2. By random, selected numbers per Region/ Subregion.

Monte	Espinal		
	Caldén	**Algarrobal**	**Ñandubay**
9	109	203	302
23	101	204	304
12			
6			
35			
28			

Satellite scenes corresponding to the selected numbers are presented in Table 3, indicating actual region/ subregion and further specified in Appendix 5. The spatial distribution of the selected scenes is shown in Figure 3.

Table 3. Paths and Rows for corresponding Landsat TM scene.

N°	Path/Row	Region/Subregion
6	P232/R081	Monte
9	P232/R084	Monte
12	P231/R078	Monte
23	P230/R085	Monte
28	P229/R088	Monte
35	P227/R089	Monte
101	P230/R083	Espinal Caldén
109	P228/R086	Espinal Caldén
203	P228/R082	Espinal Algarrobal
204	P228/R083	Espinal Algarrobal
302	P227/R082	Espinal Ñandubay
304	P226/R081	Espinal Ñandubay

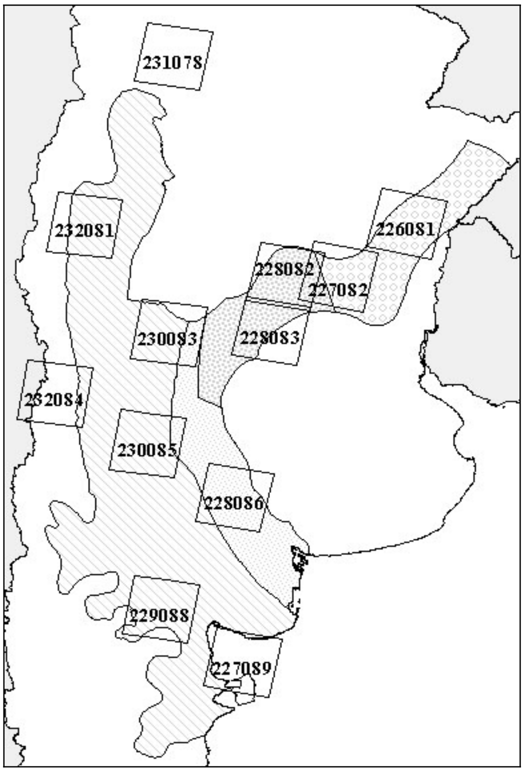


Figure 3 Spatial distribution of the sample of satellite scenes, within each region respectively.

One of the twelve selected scenes, P231/R078, did not have any actual cover within the studied regions of Monte and Espinal and it was therefore excluded from the sample (figure 3).

2.1 Preparation of digital Satellite scenes for interpretation

The Native Forest Division in Argentina provided the selected Landsat TM scenes in digital version, BSQ format, including the six bands[2] 1, 2, 3, 4, 5 and 7. The chosen scenes had been picked out by the Consortium CAC for the national forest inventory and were shot mainly in the period of January - February with a low coverage of clouds.

For the interpretation of forest cover, the digital satellite scenes were converted into three band multispectral TIFF images by the image processing software PCI. The band combination 4, 3, 5 (Near IR, Red, Shortwave IR) was used to get the best discrimination of the dry forests in the actual regions.

The PCI TIFF format was modified by the image processing software Adobe PhotoShop 4.0 so that the satellite scenes could be georeferenced and analysed by the ESRI GIS software ArcView 3.2 with the extension Image Analyst 1.0. Analogue image maps (Instituto Geográfico Militar, Appendix 3) and a digital vector map (ESRI, 1995) were employed for the georeferenciation. Four control points were indicated in each scene and the geographical co-ordinates were specified by measuring in the analogue maps or by direct links to the digital map. The scenes were all prepared in the projection UTM 1983 zone 20.

2.2 Attempt to automatic interpretation

An effort was made to find out a method to interpret, classify and discriminate the forest cover in the digital satellite scenes through automatic classification and trough classification indicated by “training areas”, but it failed due to high spectral heterogeneity within the forest areas. A wide variety in forest density and influence of grass and other ground cover with big effect on the spectral reflectance, implicated a high spectral resemblance between some native forests and brush lands, and with the GIS software used it was very difficult to separate them from each other.

2.3 Visual interpretation – phase 1

To initiate the visual interpretation of the multispectral Landsat TM scenes the bands 4, 3 and 5 were assigned the colours red, green and blue respectively. The scenes were enhanced by stretching the histograms using a *Standard Deviation* stretch, and further adjusted manually to optimise the appearance for visual interpretation and discrimination of forest cover. A Vegetative Index[3] was calculated to assist the detection of forests in the scenes. The satellite images were also plotted[4] in the scale of 1:250.000 using the band combination 4, 3, 2 (Near IR, Red, Green) with the colour assignment red, green and blue respectively to facilitate the visual interpretation.

The Argentinean Native Forest Division provided digital geographical data describing the extensions of the phytogeographical regions of *Monte* and *Espinal*. The original data was projected in the country projection Argentina zone 3 and was reprojected into UTM 1983, zone 20, using the ArcView 3.2 Shapefile Projection Utility. The geographical extensions of *Monte*

---

[2] The Bands spectral range: 1 = 0.45-0.52µm, 2 = 0.52-0.60µm, 3 = 0.63-0.69µm, 4 = 0.76-0.90µm, 5 = 1.55-1.75µm, 7 = 2.08-2.35.

[3] Normalised Difference Vegetation Index (NDVI) = (IR-R)/(IR+R), where IR is the Near IR band and R is the Red band.

[4] Satellite images plotted by Earth Satellite Corporation in Rockville, USA.

and *Espinal*, completed with the subregions of *Espinal*; *Ñandubay*, *Algarrobal* and *Caldén* are shown in Figure 2.

The satellite scenes were interpreted at the visual scale of 1:100.000[5] in an ArcView project using a View projected in UTM 1983, zone 20. Native forests and forest plantations within the study area of each satellite scene were delimited by screen digitalisation and saved as an ArcView Shape File, *Forest Cover*, with the attributes *Area* and *Forest type*, where the attribute *forest type* consisted in Native forest or Plantation. Smallest native forest formation interpreted and delimited was 3 ha for while for forest plantation it was 1 ha because of the organised structure of planted tree formation. Areas within the extension of actual region were interpreted for each satellite scene, independent of scenes overlapping.

2.4 Ground-truthing

A field visit was planned together with professional officers at the Argentinean Native Forest Division, to verify the visual interpretation of forest cover in the satellite scenes. Due to the rain season, it would have been too complicated to visit some of the areas, since the roads were in a very bad condition for transportation. To co-ordinate the mission with the Argentinean Native Forest Division a limited time available for field control was considered. The most remote areas were therefore excluded and along with the recommendations from forestry officers at the Argentinean Native Forest Division, representative areas with different types of forest were picked out for ground-truthing. The areas selected covered the Province of *La Pampa* and the southern part of *San Luis* and included the two satellite scenes P228/R086 and P230/R085, Figure 4.

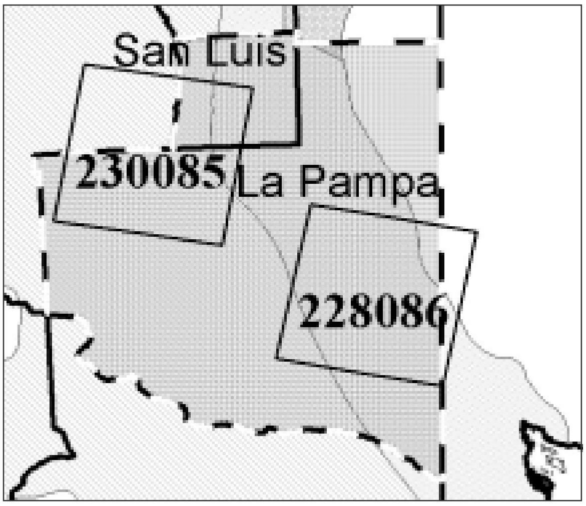


Figure 4 Area for ground-truthing

A vehicle and several road maps were provided by the Argentinean Native Forest Division to carry out the field visits. Forest areas and areas with an undefined forest resembling ground cover indicated in the visual satellite scene interpretation were visited and the actual ground cover was verified and its vegetation described. Pictures were taken to illustrate the different types of vegetation and some control points[6] were registered with a GPS[7] for later evaluation and calibration of the visual interpretation using “training areas”. Control points were also captured outside the extension of the actual satellite scenes to complement the evaluation with additional training areas.

[5] The View map scale 1:150 000 was applied, which gives an actual scale of 1:100 000, employing a 19’’ screen and the screen resolution 1024*768.
[6] The co-ordinates Latitude/Longitude (WGS84) for the actual spot visited.
[7] The Global Positioning System (GPS) Garmin 12XL was used for the capture and storage of map co-ordinates.

2.5 Evaluation of visual interpretation using data from ground-truthing – phase 2

For the evaluation of the visual interpretation of forest cover in the satellite scenes the co-ordinates[8] from the control points captured in field was presented as an event theme, Figure 5, in ArcView and the theme attribute table (Appendix 2) complemented with vegetation descriptions and vegetation classifications[9]. The training areas was defined by the control point co-ordinates and served to calibrate the visual interpretation of forest cover in all satellite scenes.

To complement the training area evaluation, the Argentinean Native Forest Division facilitated an extra sample of cut satellite scenes (Figure 5) covering the control points captured outside the extension of the actual satellite scenes.

The control points in dense shrubs, interpreted as forests in phase 1, were used to correct the visual interpretation of all twelve scenes. For the rest of the control points only misinterpretations in the visited area were corrected, since it was difficult to distinguish different wooded vegetation from each other without field controls.

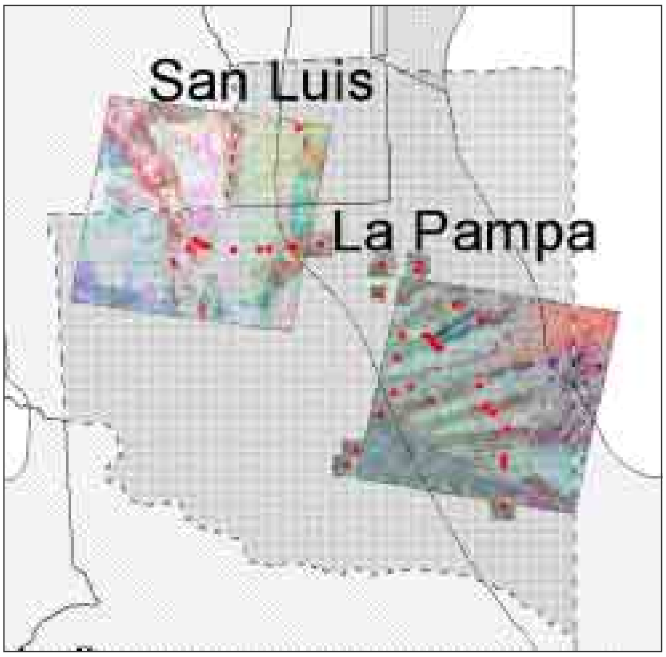


Figure 5 Distribution of control points captured in field visit, presented on corresponding satellite scenes and complementary set of cut scenes.

2.6 Forest area estimation

2.6.1 Area calculation of forest formations in sample

The delimited forest area was calculated automatically with the area calculate script *View.Calculate.Area*, writing the area for every polygon to the "Area" field in the attribute table. The area is given in the map units of the View, which is meter in the UTM 1983 zone 20 projection, and thus resulting in square meters. The extensions of the regions/subregions of *Monte* and *Espinal* were here used as masks to exclude forests outside the study areas.

---

[8] Co-ordinates in the format degrees (-DD,DDDDD).

[9] Native Forest, Open Native Forest with pasture, Burned Native Forest, Shrubs, Meadow.

2.6.2 Estimation of total forest cover

Two methods were employed to estimate the forest cover in each region/subregion. The first method applied partial aggregation ($[C_1/A_1+C_2/A_2+C_3/A_3+C_n/A_n]/n * A_{tot}$[10]) and calculated the local concentration of forest cover in each satellite scene; then it calculated the arithmetic mean of all the local forest concentrations and weighted it with the total area of the region/subregion. This method gives equal importance to every one of the interpreted satellite scenes without taking in consideration the actual studied area, meaning that a small area contributes with its forest concentration with the same weight as a big area.

The second method made a global proportional estimation $(C_1+C_2+C_3+C_n)/(A_1+A_2+A_3+A_n) * A_{tot}$[10] and calculated the forest concentration for all satellite scenes together. It was based on the total forest cover of all scenes, divided by the total interpreted area, and then weighted it with the total area of the region/subregion. This method is more "straight on" and treats the sum of all interpreted areas without contemplating the contribution of each satellite scene, which gives higher importance to the scenes with a larger studied area.

[10] C_1 = forest area in interpreted part of satellite scene "1", A_1 = total area of interpreted part of satellite scene "1" and A_{tot} is the total area of the region/subregion.

3 Results

The forest area in the regions/subregions of *Monte* and *Espinal* was estimated for both native forests and plantations and the results are shown in Table 4 together with total land area of the region/subregion.

Table 4. Forest area in each Region/Subregion by two different statistical estimations

Phytogeographical Region/Subregion	Total land area* (000 ha)	Estimated forest area (000 ha)			
		Method 1		Method 2[11]	
		Native forests	Plantations	Native forests	Plantations
Espinal - *Ñandubay*	*9 769*	*52.2*	*22.0*	*78.3*	*25.0*
- *Algarrobal*	*7 536*	*3.9*	*31.0*	*5.7*	*42.5*
- *Caldén*	*10 622*	*472.3*	*0.3*	*777.6*	*2.4*
	27 927	**528.4**	**53.3**	**861.6**	**69.9**
Monte	**50 509**	**35.7**	**0.4**	**56.4**	**0.6**

* Area estimated through digital map on phytogeographical regions presented by the Argentinean Native Forest Division

3.1 Native Forests

Total native forest area in the region of *Espinal* was estimated to between 528 400 ha Method 1, and 861 600 ha Method 2 (Table 4), corresponding to a forest cover of 1.9 – 3.1 percent in the region. The native forests in the region of *Espinal* were mainly concentrated to the subregion of *Caldén*, with about 90 percent of the region's total forest cover. The remaining 10 percent were basically fund in the subregion of *Ñandubay*, whilst the subregion of *Algarrobal* comprised less than 1 percent of the region's total native forest cover.

In the region of *Monte* the native forest formations were sparse, estimated to between 35 700 ha Method 1 and 56 400 ha Method 2, corresponding to a forest cover of 0.07 – 0.11 percent in the region.

3.2 Plantations

In the region of Espinal the extension of plantations was moderate, between 53 300 ha Method 1 and 69 900 ha Method 2 (Table 4) forming 0.19 – 0.25 percent of the land cover in the region. The forest plantations in the region of Espinal were distributed mainly between the subregions of *Algarrobal* and *Ñandubay* with around 60 and 40 percent respectively.

The appearance of plantations in the region of Monte was very sparse with a total area of 400 ha Method 1 to 600 ha Method 2.

[11] The result of this method was not employed for the final total forest cover estimation due to its statistically poor characteristics.

4 Discussion

4.1 Sampling methodology

4.1.1 Stratified Random Sampling

The sample of satellite scenes was based on scenes located in the actual regions of *Monte* and *Espinal*. Due to a big heterogeneity in distribution of forest formations in the region of *Espinal* this region was divided into three subregions, Ñandubay, Algarrobal and Caldén, to perform a stratified sampling which better reflected the distribution of the forest formations. The region of *Monte* represented a larger area than the region of *Espinal*, but because of the bigger heterogeneity in the region of *Espinal* it was motivated to assign six satellite scenes to both regions, whereof two scenes was assigned to each one of the subregions of *Espinal*.

The sample of the satellite scenes was stratify-oriented and selected by random. However when the outcome of the random selection resulted in a distribution of scenes not reflecting the composition of vegetation in the regions/subregions, according to forestry officers at the Native Forest Division, the random function was reinitiated until an acceptable distribution was achieved.

Preparing the selected scenes for interpretation it turned out that one of the scenes, P231/R078, did not fall inside the extension of the actual region *Monte* and was therefore excluded from the sample. So finally the sample consisted of 11 scenes. The loss of one satellite scene in the sample for the region of *Monte* was to some extent compensated by satellite scenes in the region of *Espinal* overlapping into the region of *Monte*, see Figure 3.

4.1.2 Methods for total forest area estimation

As a consequence of the sample method the different satellite scenes represented areas of different size within the actual regions. Two methods were employed to estimate the total forest cover in each region/subregion. The first method, based on a partial aggregation, gives equal importance to each interpreted satellite scenes without considering the actual area studied contrary to the second method, based on global proportional estimation which considers the forest area in each scene, rather than the forest concentration. Because of varying studied area in the different scenes only the first method gave a statistically recognised outcome, since the second method gave higher importance to the scenes with a larger area studied. Due to its statistically poor characteristics, the results from the second method were not employed in the final estimation of the total forest cover.

4.2 Difficulties in vegetation interpretation

The identification of native forests in dry zones as *Monte* and *Espinal* is rather difficult taking in consideration that the types of forest in these semiarid regions do not reach any appreciable heights and that the spectral characteristics are very similar to dense shrubs in satellite images. The main difficulty was to distinguish open forests from shrubs. The problem was partly a matter of the definitions between forest and shrubs, as described in FRA Working Paper 1 (FAO, 1998) and partly a question of the influence the ground vegetation had in the spectral reflection from open forests.

Since forest is defined by a composition of trees, and the definition of tree is wooded species that reach a height of at least 5 meters under ideal conditions, many of the forest formations did not differ much from the high growing shrubs, which made it technically complicated to determine whether it was a forest or just dense high growing shrubs.

In the open forests ground vegetation had a big effect on the total spectral reflection, especially if the ground vegetation was grass. The spectral signal from grasses depends much on the growing stage of the grass. When the grass is fresh and growing fast it has a high reflection in Near IR, indicating a large amount of growing biomass and thus contributing to the growing biomass in the forest, whilst withered grass does not absorb much radiation of any wavelength and therefore gives a very high total spectral reflection. The relation between the reflection in Near IR and the total spectral reflection from withered grass implicates a very small amount of growing biomass which can totally overcome the existence of open forests.

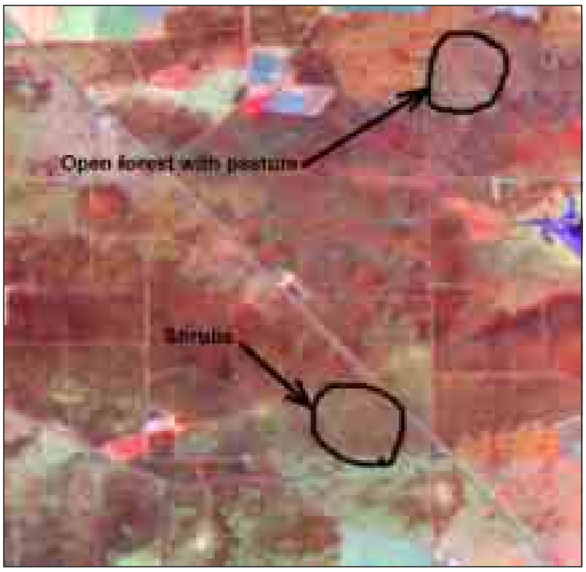


Figure 6 Similarity in spectral signal between shrubs and open forest with pastures.

Figure 7 Open forest with a ground cover of dry grass giving a spectral reflectance similar to dense shrubs.

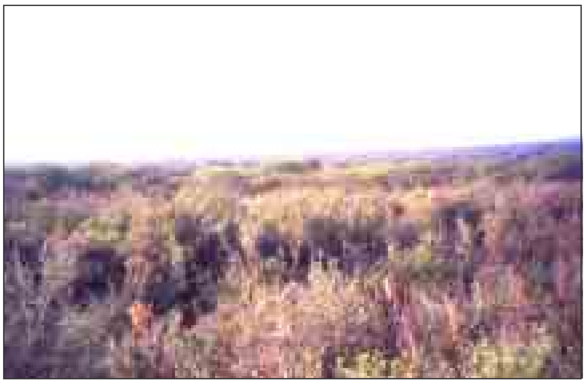


Figure 8 Dense medium height shrubs.

4.3 The dates of the satellite scenes

The date when the satellite scenes were shot influences significantly the interpretation of the vegetation. If a scene is shot during the dry season (low growing season in studied areas) the detection of woody vegetation will, in these semi-arid regions, be affected negatively and their extension be underestimated.

Most of the satellite scenes in the sample were shot during December – March (Appendix 5), which is the active growing season with maximum vegetation foliage in the studied area. However, due to difficulties in acquiring cloud free scenes, some of the scenes shot in May respectively September were employed. Variation in time for different scenes leads to a variation in forest area detected by the interpretation. This variation is however hard to quantify without reviewing time series of satellite scenes.

4.4 Actual extension of the regions of Monte and Espinal

The geographical extensions of the phytogeographical regions/subregions of *Monte* and *Espinal* are relative and change dynamically over the years depending on changes in the macroclimate. The exact actual extension of the regions can therefore not be determined until the national forest inventory is completed. In the sample, the extensions for the Regions of *Monte* and *Espinal* are the ones actually employed by the Argentinean Native Forest Division in their definition of phytogeographical zones of Argentina. Changes in the regional extensions can therefore be required and thus affect the result of this study.

4.5 Ground-truthing

4.5.1 Areas selected for ground-truthing

The field visit to verify the visual interpretation of the satellite scenes was carried out together with the Argentinean Native Forest Division as a joint effort mission. Due to restricted financial and time resources the field visit was limited to one week and concentrated to a zone with forest formations representative for major parts of the studied regions. The limited area visited for ground-truthing is not to be considered as a major bias in the calibration of the interpreted satellite scenes, since the training areas selected were representative for major parts of the regions and since the scenes outside the visited area did not comprise major forest formations.

4.5.2 Correlation between visual interpretation and ground control

During the field visit control points were selected according to their accessibility and representativity and they were captured with GPS to make a good representation of different types of vegetation cover, as training areas for calibration of the visual interpretation. Without claiming any quantitative estimation of the error in the calculation of forest cover, the control points were employed to give an indication of the precision in the area estimates. In total, 33 control points (Appendix 2) were located within the study area and used for this error indication. 13 of the control points were in the visual interpretation set as *forest cover* and 20 as *non-forest cover* (Table 5).

Table 5. Correlation between visual interpretation and ground control, showing number of control points in either forest area or none-forest area.

Ground Control		Visual Interpretation		TOTAL
		Forest	Not Forest	
Forest	- *without pasture*	*9*	*3*	
	- *with pasture*	*2*	*3*	
		11	**6**	**17**
Not Forest	- *Burnt Area*		*2*	
	- *Shrubs*	*2*	*9*	
	- *Grassland*		*3*	
		2	**14**	**16**
TOTAL		**13**	**20**	**33**

Of total 16 control points in non-forest areas 12 percent were interpreted as forests. Saying that of the forest cover interpretations 85 percent were proved to be forest areas in the ground control while remaining 15 percent were non-forest areas. These 15 percent (two control points) were in fact shrubs that had a similar spectral reflection to forest areas and represented large areas in the satellite scenes. These "forest-like" shrub areas were corrected in the second phase of the interpretation.

Of the non-forest cover interpretations 70 percent were proven to be area without forest cover while remaining 30 percent turned out to be forest areas. Saying that of total 17 control points in forest areas 65 percent were interpreted as forests of which 70 percent were forests without pasture and 30 percent forests with pasture. 75 percent of the forests without pasture were interpreted as forest areas while only 40 percent of the forests with pasture were interpreted as forest areas, indicating an underestimation of forest cover, especially in areas of open forests with pasture. Correction of these misinterpreted control points was only applied within the visited area, since it was difficult to distinguish with precision the different woody vegetation types from each other without field controls.

To get more accurate estimations of the precision in the results of the study more control points must be registered and be more systematically sampled.

4.6 Conclusions

This study presents an estimation of the native forest in the regions of Monte and Espinal: 36 000 ha and 530 000 ha respectively. Even though the figures presented by this study imply an underestimation of the forest cover, they are significantly lower than earlier estimations made by Argentinean authorities (1 900 000 ha and 3 200 000 ha, see Appendix 1). The big difference in the results achieved, indicates that a revision of earlier Argentinean forest cover statistics is needed and that further efforts should be made to update them.

FRA 2000 applies available data and will therefore have to rely on data compiled from provincial and regional inventories of different quality (Appendix 1) where the ongoing national forest inventories not will be able to in time provide the information required.

References

Corinaldesi, L., 1998. *Argentina, Sector Forestal,* Argentina, SAGPyA, 85 pp.

ESRI, 1995. *Digital Chart of the World*. Available at http://gisstore.esri.com/acb/showdetl.cfm?&Product_ID=313

FAO, 1998. *FRA 2000 Terms and Definitions – Working paper 1*. Rome, FAO, 18 pp.

Fernández, R., 1999. *SAGPyA Forestal*. Buenos Aires, Argentina, 50 pp.

IFONA, 1987. *Anuario Estadística Forestal y Pre-Carta Forestal Nacional*. Buenos Aires, Argentina.

Instituto Geográfico Militar. *Topographic maps 1:250.000*. Buenos Aires, Argentina.

Maradei, D., 1999. *Plan Forestal Nacional*. SAGPyA, Unidad de Comunicación Argentina, 58 pp.

Montenegro, C., 2000. *Informe para: Fundación Amistad Americana – FRA 2000, FAO. Enero 2000.* Buenos Aires, Argentina. 8 pp.

SAGPyA, 1998. *SAGPyA Forestal N. 5,* Dic 1997 - Feb 1998.

SDSyPA, 2000. *Misiones - Digital image, final version*. *Format bitmap, BMP*. Argentina, Secretaría de Desarrollo Sustentable y Política Ambiental.

SRNyDS, 1998. *Primer Inventario Nacional Bosques Nativos, Sumario.* Préstamo BIRF N. 4085. Argentina, Secretaría de Recursos Naturales y Desarrollo Sustentable, 13 pp.

Appendix 1: Native forest statistics available at the Native Forest division, Ministry of Social Action.

Evaluation of the Forest Resources Year 2000
(Report for FRA 2000)

Native forests area estimated 1989 (000 ha).

Phytogeographical region	Total area[12]	Forest area[13]
Parque Chaqueño	67.850[14]	25.750
Selva Tucumano-Boliviana	4.550	2.490
Selva Misionera	3.020[15]	2.060
Bosques Andino Patagónicos	9.240[16]	1.970
Monte	46.080	1.880
Espinal	18.430	3.230[17]
TOTAL	**149.170**	**37.380**

Extension of different vegetation types in the region of *Misiones* presented in land use classes (000 ha).

		Native Forests	Shrubs	Plantations	Agriculture
Forest	*- Native Forests*	923.605			
	- Gallery Forests	3.935			
AgroForestry		573.400	446.734	224.771	747.129
Other Wooded land	*- Sugar cane fields*	48.387			
Other land	*- Livestock farms*	92	104	29.859	21.104
TOTAL		**1.549.419**	**446.898**	**254.630**	**768.233**

Source: Native Forest Division at the Secretariat for Sustainable Development and Environment Politics, Ministry of Social Action.

[12] Source: Native Forest Division at the Secretariat for Sustentable Development and Environment Politics, Ministry of Social Action. Information derived by the Argentinean-Canadian Forest Consortium (Aeroterra-Simons-Tecsul) responsible for the execution of the first national inventory of native forests under the project of Native Forests and Protected Areas (BIRF Nº 4085-AR).

[13] Data with low dependability estimated from provincial inventories and reports, satellite images and a preliminary national forest appraisal. Source: Native Forest Division at the Secretariat for Sustentable Development and Environment Politics, Ministry of Social Action. Information covering all of the regions will be available in April 2001.

[14] Source of low dependability from regional map over Argentinean Natural Regions.

[15] Source of high dependability from the first national inventory of native forests. Satellite images from Landsat/TM year 1997 verified in field.

[16] Source of high dependability from the first national inventory of native forests. Satellite images from Landsat/TM year 1997/1998 verified in field for the whole region except for the province of Tierra del Fuego where satellite SPOT images from 1995 were used.

[17] Total forest area for Espinal comprises the “Parque Pampeano-Puntano” 1 790 000 ha and the “Parque Mesopotámico” 1 400 000 ha.

Appendix 2: Geographical co-ordinates, vegetation descriptions and classification for control points captured in field visit

North (Degrees)	**East (Degrees)**	**Vegetation Description**	**Field Check Classification**	**Interpretation Classification**
-37.89515	-65.47684	Steppe, low shrubs without trees	Shrubs	n.a.*
-36.29068	-66.82969	Medium seized shrubs	Shrubs	Not forest
-36.27853	-66.87219	Medium seized shrubs	Shrubs	Forest
-36.24265	-66.92430	Medium seized shrubs	Shrubs	Not forest
-36.40692	-67.14017	Medium seized shrubs	Shrubs	Not forest
-36.31043	-65.75530	Burnt forest	Burnt field	n.a.*
-36.70440	-65.22024	Wide forest areas	Forest	n.a.*
-35.41301	-65.92651	Native forest, trees and shrubs	Forest	Forest
-37.11787	-64.64522	Towards south open forest with much pasture	Forest-Pasture	Not forest
-37.11476	-64.68869	Shrubs with dead trees	Shrubs	Not forest
-37.09447	-64.70845	Dead trees (burnt)	Burnt field	Not forest
-37.06291	-64.73668	Towards west forest, towards north dead trees	Forest	Not forest
-37.02560	-64.77495	Towards south forest	Forest	Not forest
-37.02579	-64.79808	Towards north forest	Forest	Not forest
-37.02302	-65.00161	Forest	Forest	Forest
-37.19564	-65.05736	Forest	Forest	Forest
-37.42189	-64.93998	Forest with pasture	Forest-Pasture	Forest
-37.41792	-64.28976	Dense forest	Forest	Forest
-37.57112	-64.23092	Dense shrubs with trees, forest	Forest	Forest
-37.63005	-64.15958	Open forest with pasture	Forest-Pasture	Forest
-37.75036	-64.02606	Towards south dense shrubs and trees	Forest	Forest
-38.33624	-64.07278	Front to “Monte”, dense shrubs, Jarilla	Shrubs	n.a.*
-38.01338	-64.06892	Towards east scarce low trees with pasture	Forest-Pasture	Not forest
-37.96784	-64.06890	Towards east trees with some pasture	Forest-Pasture	Not forest
-37.52869	-64.74452	Towards west burnt field	Burnt field	Not forest
-37.45918	-65.09650	Shrub steppe, dead trees	Shrubs	Not forest
-36.47508	-64.83842	Chañar, shrubs	Shrubs	n.a.*
-36.79544	-64.50746	Caldenal forest south of route 14	Forest	Forest
-36.91923	-64.27125	Caldenal, dense forest	Forest	Forest
-37.62653	-65.23763	Shrub steppe, Monte	Shrubs	Not forest
-36.47961	-65.18821	Caldén forest	Forest	n.a.*
-36.33430	-66.24137	Pasture, Monte	Pasture	Not forest
-36.33581	-66.32758	Pasture, Monte	Pasture	Not forest
-36.33417	-66.56991	Pasture, Monte	Pasture	Not forest
-36.32203	-66.00943	High dense shrubs - trees	Forest	Forest
-36.52876	-64.86149	Caldén forest	Forest	n.a.*
-36.33060	-66.04497	Low dense shrubs	Shrubs	Not forest
-36.29587	-66.81617	Low shrubs	Shrubs	Not forest
-38.00567	-65.57563	Shrubs and pasture without trees	Shrubs	Not forest
-36.30886	-66.99907	Saline, low shrubs	Shrubs	Forest

* Not applicable sample plots as they were taken outside of the study area.

Appendix 3: Maps used to georeference the twelve satellite scenes in the study

Maps in the scale of 1:250.000 from the Military Geographical Institute

Line maps* :	3566-III	(1:250 000)
	3766-I	(1:250 000)
	4166	(1:500 000)
Image maps* :	2566-IV	(1:250 000)
	3160-II	(1:250 000)
	3160-III	(1:250 000)
	3163-IV	(1:250 000)
	3169-II	(1:250 000)
	3366-III	(1:250 000)
	3363-II	(1:250 000)
	3363-IV	(1:250 000)
	3566-III	(1:250 000)
	3569-I	(1:250 000)
	3763-III	(1:250 000)
	3766-I	(1:250 000)

***** The maps are based on a composition of Landsat TM images projected in Gauss-Krüger, International Ellipsoid (WGS 84), Reference system POSGAR 94, Geodesic Datum (horizontal) Campo Inchauspe 1969, Longitude referred at the Greenwich Meridian.

Appendix 4: Forest area detected in the satellite scenes, presented by region/subregion

Forest area detected in each of the twelve studied satellite scenes, presented by Region/Subregion, (ha).

	ESPINAL (27,927,000 ha*)												**MONTE** (50,509,000 ha*)			
	Caldén (10,622,000 ha*)				**Algarrobal** (7,536,000 ha*)				**Ñandubay** (9,769,000 ha*)							
Landsat TM (Path/Row)	Interpreted area (ha)	Native Forest (ha)	Plantation (ha)	Forest Total (ha)	Interpreted area (ha)	Native Forest (ha)	Plantation (ha)	Forest Total (ha)	Interpreted area (ha)	Native Forest (ha)	Plantation (ha)	Forest Total (ha)	Interpreted area (ha)	Native Forest (ha)	Plantation (ha)	Forest Total (ha)
P226/R081									2,430,897	22,929	7,875	30,804				
P227/R082					754,174	-	625	625	2,010,655	13,243	3,555	16,798				
P227/R089													354,770	252	-	252
P228/R082					2,659,512	3,741	26,215	29,956	68,821	-	121	121				
P228/R083					1,905,834	285	3,170	3,455								
P228/R086	2,551,548	245,670	-	245,670									228,500	-	-	-
P229/R088													2,761,947	-	-	-
P230/R083	637,719	2,184	59	2,243									2,109,984	-	-	-
P230/R085	363,937	12,260	-	12,260									2,868,855	12,134	-	12,134
P232/R081													2,307,654	-	125	125
P232/R084													469,515	-	-	-
TOTAL	3,553,204	260,114	59	260,173	5,319,520	4,026	30,010	34,036	4,510,373	36,172	11,551	47,723	11,101,22	12,386	125	12,511

* Total area of region/subregion

Appendix 5: Satellite scenes employed by current study

Landsat 5 TM Satellite scenes employed by current study

Product number	Path/Row	Acquisition date
99189002978	226/081F	19990115
99120002653	227/082F	19990106
99190002997	227/089F	19981205
98216001428	228/082F	19980518
99168002910	228/083F	19970328
99189002968	228/086F	19990113
99190002982	229/088F	19990205
98203001443	230/083F	19970902
99192003011	230/085F	19990111
99189002962	232/081F	19990210
99189002963	232/084F	19990210

FRA Working Papers

0. How to write a FRA Working Paper (10 pp. – E)
1. FRA 2000 Terms and Definitions (18 pp. - E/F/S/P)
2. FRA 2000 Guidelines for assessments in tropical and sub-tropical countries (43 pp. - E/F/S/P)
3. The status of the forest resources assessment in the South-Asian sub-region and the country capacity building needs. Proceedings of the GCP/RAS/162/JPN regional workshop held in Dehradun, India, 8-12 June 1998 (186 pp. - E)
4. Volume/Biomass Special Study: georeferenced forest volume data for Latin America (93 pp. - E)
5. Volume/Biomass Special Study: georeferenced forest volume data for Asia and Tropical Oceania (102 pp. - E)
6. Country Maps for the Forestry Department website (21 pp. - E)
7. Forest Resources Information System (FORIS) – Concepts and Status Report (20 pp. E)
8. Remote Sensing and Forest Monitoring in FRA 2000 and beyond (22 pp. - E)
9. Volume/Biomass special Study: Georeferenced Forest Volume Data for Tropical Africa (97 pp. – E)
10. Memorias del Taller sobre el Programa de Evaluación de los Recursos Forestales en once Países Latinoamericanos (194 pp. - S)
11. Non-wood forest Products study for Mexico, Cuba and South America (draft for comments) (82 pp. – E)
12. Annotated bibliography on Forest cover change – Nepal (59 pp. – E)
13. Annotated bibliography on Forest cover change – Guatemala (66 pp. – E)
14. Forest Resources of Bhutan - Country Report (80 pp. – E)
15. Forest Resources of Bangladesh – Country Report (93 pp. – E)
16. Forest Resources of Nepal – Country Report (78 pp. - E)
17. Forest Resources of Sri Lanka – Country Report (77 pp. – E)
18. Forest plantation resource in developing countries (75 pp. – E)
19. Global forest cover map (14 pp. – E)
20. A concept and strategy for ecological zoning for the global FRA 2000 (23 pp. – E)
21. Planning and information needs assessment for forest fires component (32 pp. – E)
22. Evaluación de los productos forestales no madereros en América Central (102 pp. – S)
23. Forest resources documentation, archiving and research for the Global FRA 2000 (77 pp. – E)
24. Maintenance of Country Texts on the FAO Forestry Department Website (25 pp. – E)
25. Field documentation of forest cover changes for the Global FRA 2000 (40 pp. – E)
26. FRA 2000 Global Ecological Zones Mapping Workshop Report Cambridge, 28-30 July 1999 (53 pp. –E)
27. Tropical Deforestation Literature:Geographical and Historical Patterns in the Availability of Information and the Analysis of Causes (17 pp. – E)
28. Global Forest Survey – Concept Paper (30 pp. - E)
29. Forest cover mapping and monitoring with NOAA-AVHRR and other coarse spatial resolution sensors (42 pp. - E)
30. Web Page Editorial Guidelines (22 pp. – E)
31. Assessing state & change in Global Forest Cover: 2000 and beyond (15 pp. – E)
32. Rationale & methodology for Global Forest Survey (60 pp. – E)
33. On definitions of forest and forest change (13 pp.- E)
34. Bibliografía comentada. Cambios en la cobertura forestal: Nicaragua (51 pp. – S)
35. Bibliografía comentada. Cambios en la cobertura forestal: México (35 pp. – S)
36. Bibliografía comentada. Cambios en la cobertura forestal: Costa Rica (55 pp. – S)
37. Bibliografía comentada. Cambios en la cobertura forestal: El Salvador (35 pp. – S)
38. Bibliografia comentada. Cambios en la cobertura forestal: Ecuador (47 pp. – S)
39. Bibliografia comentada. Cambios en la cobertura forestal: Venezuela (32 pp. – S)
40. Annotated bibliography. Forest Cover Change: Belize (36 pp. – E)
41. Bibliografia comentada. Cambios en la cobertura forestal: Panamà (32 pp. – S)
42. Proceedings of the FAO Expert consultation to review the FRA 2000 methodology for Regional and Global Forest Change Assessment (54 pp. – E)

43 Bibliografia comentada. Cambios en la cobertura forestal: Colombia (32 pp. – S)
44 Bibliografia comentada. Cambios en la cobertura forestal: Honduras (42 pp. – S)
45 Proceedings of the South-Asian Regional Workshop on Planning, Database & Networking for Sustainable Forest Management (254 pp. – E)
46 Under preparation
47 Proceedings of the Regional workshop on forestry information services, Stellenbosch, South Africa, 12-17 february 2001

Please send a message to fra@fao.org for electronic copies or download from www.fao.org/forestry/fo/fra/index.jsp (under Publications)