

Potential for a remote-sensing-aided forest resource survey for the whole globe

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The Global Forest Resources Assessment 2000 included a pan-tropical remote-sensing survey to augment information provided by countries; is it feasible to extend this type of survey to the entire world?

The Global Forest Resources Assessment 2000 (FRA 2000) relied primarily on information provided by countries, but FAO also conducted a remote-sensing study of tropical forests to complement country information and to bolster understanding of land-cover change processes in the tropics, especially deforestation, forest degradation, fragmentation and shifting cultivation. Remote-sensing-based inventory can help confirm estimates obtained from other sources, and can also contribute to country capacity building through possible regional or national training centres. This article considers the feasibility of extending remote-sensing-aided forest resource survey, independent of countries' traditional inventories, to the whole globe in

FRA 2010. The emphasis would be on global-level estimates of area change for forest and other wooded land, which would be constructed from estimates at the regional level, with a possible distinction into temperate, boreal and tropical zones.

The tropical remote-sensing surveys in FRA 1990 and FRA 2000 were carried out using visual interpretation. The main advantage of visual interpretation is that contextual information and expert knowledge can be used in the analysis more easily and sometimes more accurately than through digital methods. However, visual interpretation is laborious and subjective. These drawbacks are more critical in global surveys with varying vegetation zones. Areas with sparse tree cover, such as semi-arid lands and boreal

*Very-high-resolution
1 m Ikonos
panchromatic 1:20 000
map subset, Lohja,
Finland*



NATIONAL LAND SURVEY OF FINLAND



NATIONAL LAND SURVEY OF FINLAND

*The same area seen in
a high-resolution
Landsat 5 TM image*

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tundra woodland, are especially difficult to evaluate.

The availability of reference data for digital image analysis or visual interpretation is one of the key problems in remote-sensing-aided global surveys. All remote-sensing based forest resource surveys need to be supported by field observations or measurements. In principle, a certain minimum number of field plots is needed for each image. This requirement can be partly overcome by relative calibration of images, which makes it possible to use reference data from neighbouring images. Field sampling intensity depends on the available technical and financial resources, the variability of the target parameters in the field and the remote-sensing application used.

The parameters that can be estimated using remote-sensing-aided survey depend on the intensity of the field sampling. Parameters that require quality control most urgently and for which the available resources provide possibilities for remote-sensing-aided survey include area of forest land, other wooded land and other land, as well as their changes. These variables were measured in FRA 2000. A breakdown into rough species groups, e.g. coniferous, broadleaved and mixed forests, may also be possible using remote sensing if field data are available. Tree stem volume and biomass are also key variables in assessing the status of the world's forests, but the estimation of these variables requires thorough field measurements. However, few studies have evaluated the accuracy of estimates for these variables using remote-sensing data combined with sparse field sampling.

Total coverage is feasible with medium-resolution data (e.g. MODIS). Medium-resolution satellite images and wall-to-wall land cover maps provide information sources for planning both field-measurement-based and remote-sensing-based sampling designs.

Depending on the objective of the global survey, the price of the images and the workload, sampling may be the only feasible way to use high-resolution (e.g. Landsat, with resolution ranging from 15 to 60 m) or very-high-resolution (e.g. Ikonos and QuickBird, the first two satellites that can produce images with pixel size below 1 m) remote-sensing data. With Landsat satellite images – the most widely used high-resolution images – about 400 to 450 images are needed for 10 percent sampling of the entire globe, and the esti-

mated cost would be about US\$255 000 (Table 1). A survey based purely on field measurements, in contrast, could cost from US\$10 million to around US\$100 million (Table 2).

Change analysis requires double coverage of images, and sufficient very-high-resolution images may not be available; in this case a multi-resolution technique may have to be adopted.

The authors calculated rough error estimates under different sampling densities for the area of forest land and of other

TABLE 1. Example of number of images and estimated costs for a remote-sensing survey with different resolution and sampling options

Region	Number of images needed				Imaging cost (thousand US\$)		
	MODIS, full coverage	Landsat, 10% coverage	Ikonos, 0.1% coverage	Ikonos, 1% coverage	Landsat, 10% coverage	Ikonos, 0.1% coverage	Ikonos, 1% coverage
Africa	6	97	331	3 309	58	951	8 992
Asia	6	100	343	3 428	60	986	9 315
Europe	4	73	251	2 511	44	722	6 824
North and Central America	4	69	237	2 374	42	683	6 453
Oceania	2	28	94	943	17	271	2 564
South America	3	57	195	1 950	34	561	5 299
Total	25	424	1 452	14 516	254	4 174	39 446

TABLE 2. An example of the number and costs of field plots in a global survey utilizing field data only

Region	Land area (million ha)	Forest area (million ha)	Field plot area ^a (ha)	Number of field plots	Estimated costs (thousand US\$)
Africa	2 978	650	13 692	69 221	30 457
Asia	3 085	548	28 540	30 010	13 205
Europe	2 260	1 039	28 268	44 751	19 690
North and Central America	2 137	549	27 814	27 421	12 065
Oceania	849	198	25 960	10 898	4 795
South America	1 755	886	21 648	49 035	21 575
Total	13 064	3 869		231 336	101 788

^a The area represented by one field plot varies depending on net change in forest area; plots are smaller in areas where annual change is greatest.

TABLE 3. Estimated costs with 100 field plots per Landsat image at US\$440 per plot (thousand US\$)

Region	Field data	Image data	Total costs
Africa	4 254	58	4 312
Asia	4 407	60	4 467
Europe	3 228	44	3 272
North and Central America	3 053	42	3 094
Oceania	1 213	17	1 229
South America	2 507	34	2 541
Total	18 661	254	18 916

wooded land in Europe and the Commonwealth of Independent States (CIS), using a simulation model based on the FRA 2000 land cover map. This study suggested that a forest survey based on high-resolution and very-high-resolution images could have relative standard errors of 5 percent or less and could meet the needs of a possible independent remote-sensing-aided global forest survey with moderate costs (Table 3).

It was assumed that forest area and area change can be interpreted from very-high-resolution images without field data; the validity of this hypothesis would have to be tested. Remote-sensing and ground-sam-

pling densities may vary by region, so this study should be extended to other regions.

New satellites, some still under development, are increasing the availability of satellite images. So far, global wall-to-wall forest cover maps have been based on low- or medium-resolution images. However, it is expected that global wall-to-wall mapping with high-resolution images will appear in a few years. This does not eliminate the need for an independent remote-sensing-aided forest resource survey using exact FAO definitions and including current state estimates, change estimates and standard errors computed under strict quality control. ♦