

# Satellite remote sensing: mapping of coffee and cocoa plantations

**F**or a producing country, knowledge of the areas planted to coffee and cocoa, along with their location and their vegetative condition is essential for defining an appropriate agricultural policy: management of land resources and regional planning, gaining an idea of future supply, introduction of supervisory infrastructures for production and collection, etc. In Côte d'Ivoire, these two crops are grown over vast expanses in often spontaneous initiatives by smallholders to develop forest zones, the dynamics of which are not completely known and are unsupervised. Consequently, although cocoa and coffee are very important export products in Côte d'Ivoire, the areas planted are not precisely known, with estimations fluctuating between 2 and 4 million hectares in all.

Such knowledge can be acquired by conventional inventories of the stands, with identification of plantations and area measurements in the field. In order to provide an alternative to these laborious and expensive conventional techniques, BNEDT-CCT (Côte d'Ivoire) and CIRAD carried out a joint study to test the feasibility of statistical inventory mapping based on Spot images and field surveys.

The methodology was developed in the department of Daloa, in central-western Côte d'Ivoire, over an area of 29,842 ha within the pilot zone of the Rural Cadastral Plan of Daloa. The map of cadastral plots, which was still incomplete, included indications of land occupation, based on 15 themes, including coffee and cocoa. Similar work was launched in the department of Soubré.

## Methodology

Various operations were carried out for this project, from a preliminary survey to validation of the classifications obtained. The sequence of these different operations is shown in figure 1.

### Preliminary agronomic survey and biometric analysis

The agronomic survey (January-February 1997) involved 358 plots, including 159 cocoa plantings and 197 coffee plantings. Only plots more than 5 years old were taken into account, thus excluding young plantings that were not agronomically stabilized. The 36 variables noted were identifiers and descriptors from agronomic, topographical, pedological and socio-economic viewpoints. A multiple correspondence analysis was carried out on all these data and revealed that, for both crops, the first axis was always an intensification axis. For instance, in the case of cocoa, it contrasted high-yielding plots in good agronomic condition with low-yielding plots, or virtually abandoned plots, often set up using the old cultivation system based on non-improved planting material (Amelonado). The level of intensification, characterized simply from the yield estimated by surveyors, was therefore an indicator that summed up both the integrity of the plots and the vegetative conditions of the trees within them, two parameters that were likely to be revealed by satellite remote sensing.

### Preliminary processing of geographical data

Different operations made it possible to match the image obtained with the satellite

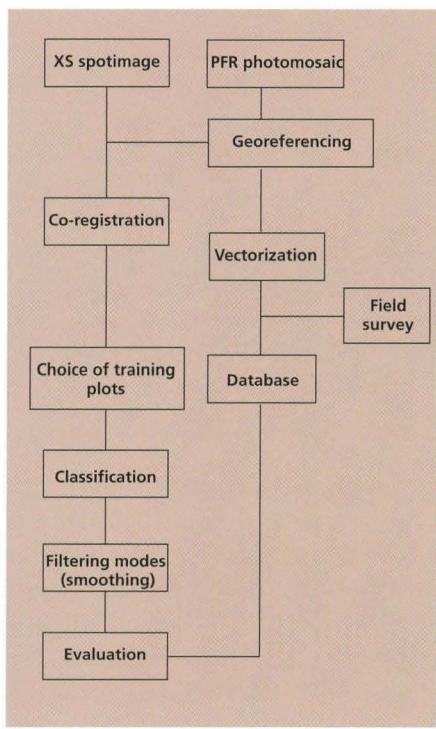


Figure 1. Diagram of operational sequence.

scene (Spot-XS 46-336 scene dated 29th March 1998) with a map comprising a 9-plate PFR photomosaic, in order to select training and check plots.

### Image classification

The classification method used was "supervised maximum likelihood classification" and was carried out in several stages:

- identification of themes (classes),
- choice of training plots,
- checking of the classification rule in the test zone,
- validation on the entire scene.

### Identification of themes and choice of training plots

An initial eight themes were defined: coffee, cocoa, forest, fallow (including food crops and cotton), wasteland (tall grasses, *Chromolæna odorata*, forest regrowth), habitat-denuded zone, cleared forest and bottomland. For these eight themes, 63 training "plots" (representative sample) were chosen, covering a total of 302 ha, i.e. 1% of the study area.

The training plots for the coffee and cocoa themes came naturally from the agronomy surveys. For the other themes, they were chosen by photo-interpretation based on the indications on the PFR photomosaic, which thus constituted the "field truth". Classification was then carried out using three channels (XS1, XS2, XS3).

A study of spectral signature separability (Jefferies-Matusita distances) showed that, generally speaking, the themes adopted were clearly separable.

### Validation in the test zone

Plot checking for the coffee and cocoa themes involved all the survey plots, except those that were abandoned and those already used for training, i.e. 174 coffee plantings and 143 cocoa plantings. The training and check plots for the other themes were chosen using the PFR photomosaic. Overall plot checking consisted of 389 elements, for 2,589 ha.

The classification was evaluated from a confusion matrix in accordance with so-called "majority" recognition (classification of the plot according to its majority theme). This corresponded to the purpose and to the results of the agronomic survey, which identified the plots according to their dominant crop.

### Validation of the whole scene

In order to validate the classification results on the whole scene, i.e. 3,600 km<sup>2</sup>, a sampling plan was drawn up in two stages: firstly stratified random sampling (based on the representativeness of the themes) of 320 uniform units of at least 5 ha, then, in order to account for access difficulties, a selection of units whose centre was located less than 1,200 m from a practicable track. 180 units were chosen in this way, 133 of which were effectively investigated, i.e. an investigation rate of 0.2%. During the validation survey, the centres of the units were located by a GPS (Global positioning system).

## Results

In the test zone (table 1 and figure 2) the theme recognition rates varied from 66% to 100%. Coffee and cocoa were recognized at

69 and 66%, respectively. The overall percentage of correctly classified pixels was 72%.

On the entire scene (table 2), coffee and cocoa were recognized at 86 and 94%. 80% of pixels were correctly classified. For these two crops, statistical precision was satisfactory: 0.86 and 0.90.

## Conclusions and prospects

Despite the numerous constraints, some of which were specific to the agriculture and tropical climatology (e.g. cloud cover in the rainy season prevents scenes from being taken), the results obtained in terms of theme recognition and statistical precision are acceptable for statistical mapping purposes. It seems they could be improved by using the mid infrared (MIR) channel.

Extension of the method to the entire cocoa and coffee growing zone of Côte d'Ivoire can thus be envisaged.

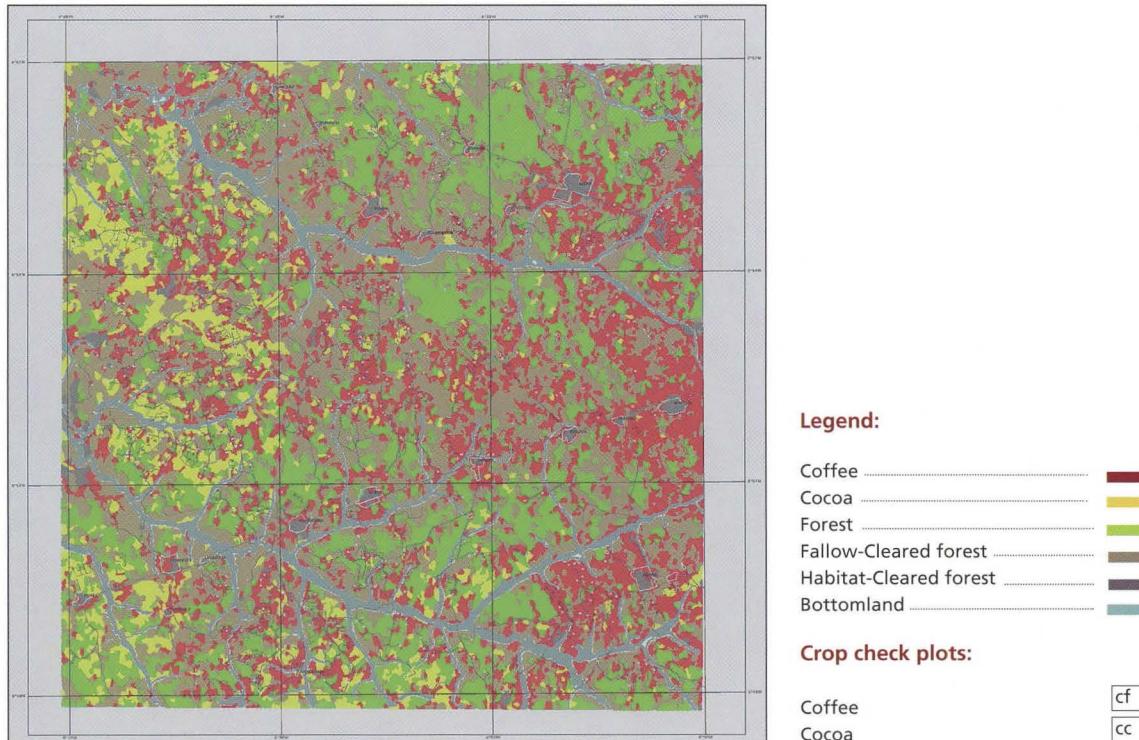
The next step of the work will be an analytical approach intended to characterize the condition of the cocoa and coffee plots and, consequently, their suitability for rehabilitation. ■

Table 1. Confusion matrix, as a percentage, omission errors on the test zone.

Theme	Classification							Omission* (%)
	1	2	3	4	5	NC	Total	
Coffee	69	22	2	2	1	3	99	31
Cocoa	20	66	7	1	4	1	99	34
Forest	3	9	87	0	0	0	99	12
FWBL	5	0	0	95	0	0	100	5
HDZCF	0	0	0	0	100	0	100	0

NC : unclassified; FWBL: recomposed theme (fallow-wasteland-bottomland); HDZCF: recomposed theme (habitat-denuded zone-cleared forest).

\*Omission for a theme A: error by which a plot belonging to the land in theme A is classified in another theme.



**Figure 2.** Classified image of the test zone.

True scale 1:30,000

**Table 2.** Confusion matrix, as a percentage, and parameters: omission and commission errors (as a %) and statistical precision ( $SP = 1 - \text{com} / 1-\text{om}$ ) on the scene.

Theme	Classification					Omission (%)	Commission* (%)	PS
	1	2	3	4	5			
Coffee	86	7	3	3	0	99	14	22
Cocoa	0	94	4	2	0	100	6	20
Forest	4	33	54	4	4	100	46	19
FWBL	30	5	0	55	10	100	45	21
HDZCF	0	0	0	0	100	100	0	20

NC : unclassified ; FWBL: recomposed theme (fallow-wasteland-bottomland); HDZCF: recomposed theme (habitat-denuded zone-cleared forest).

\*Commission for a theme, A = error by which a plot belonging in the field to theme B is classified and mapped in theme A.

### List of publications

N'DOUME C., LACHENAUD P., HUSSARD A., NGUYEN H., FLORI A., 2000. Etude de faisabilité pour l'élaboration d'une cartographie statistique d'inventaire des vergers café et cacao en Côte d'Ivoire par télédétection satellitaire. Bulletin de la Sfpt, 157, 3-10.

NGUYEN H., LACHENAUD P., FLORI A., 1997. Cartographie analytique et statistique des vergers cacao et café de deux zones pilotes (Daloa et Soubré) de Côte d'Ivoire. Montpellier, France, Cirad, CP-SIC n° 859, 60 p., cartes (internal document)

FLORI A., LACHENAUD P., NGUYEN H., 1997. Analyse statistique de l'enquête Cirad-CCT dans les zones pilotes de Daloa et Soubré. Montpellier, France, Cirad, Doc CP n° 806, 21 p., carte (internal document).