ERS-1 SAR AND OPTICAL DATA FOR LAND USE/LAND COVER MAPPING: A CASE STUDY IN A SAVANNAH ZONE OF GUINEA

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ABSTRACT

This paper presents the results of an assessment of the use of ERS-1 SAR data for land use/land cover mapping in a savannah zone of West Africa. Optical data (SPOT XS, Landsat TM) were compared with microwave data (SIR-A, ERS-1). Landsat TM data were initially geocoded with a Digital Terrain Model and then registered with ERS-1 SAR data. Multispectral SPOT data were interpreted at 1:100 000 and 1:50 000 scale. Standard and adaptive SAR filters were compared. Two methods of optical/microwave data integration were tested: Intensity Hue Saturation transformation and optical/radar colour combination. The following post-processing was applied to ERS-1 SAR images: speckle reduction, geocoding, radiometric correction and texture analysis. It appeared that identification of savannah types and land use classes was not satisfactory using ERS-1 data of a single date. Better results were obtained in the case of a multitemporal SAR approach and especially when combining dry season optical data with rainy season SAR data. In this latter case it becomes possible to define more detailed visual interpretation keys, particularly in the identification of water saturated zones, temporary ponds and assessment of flooded plain extent. The complementarity of optical satellite data and ERS-1 SAR data for flooded rice fields monitoring is very promising due to the strong backscatter variations during the crop cycle. Elements of cost analysis are also presented.

Keywords: remote sensing, land use mapping, SAR imagery interpretation, crop identification, cost analysis

1. INTRODUCTION

This paper presents the results of a technical study to assess the usefulness of ERS-1 SAR images for land cover/land use mapping in Guinea. This study was undertaken as a joint project between FAO (Food and Agriculture Organization of the United Nations), ESA (European Space Agency) and MARA (Ministère de l'Agriculture et des Ressources Animales de Guinée, Direction Nationale des Forêts et des Chasses). The project also included training activities. The project started soon after the launch of ERS-1 and follows a study on the complementarity of microwave and optical data for land use mapping in Tunisia. The interest of FAO with respect to radar imagery in tropical and equatorial zones is related to the limitations of optical sensors in regions with a persistent cloud cover and results from the important contributions of such airborne projects as Radambrasil, NIRAD (Nigeria), Proradam (Colombia) to natural resources inventory and mapping. The present project benefited from the contribution of the Remote Sensing Laboratories of the Department of Geography of Zurich University in charge of the Digital Terrain Model production and satellite data geocoding.

2. OBJECTIVE

The principal objective of this study is to assess the usefulness of ERS-1 SAR images for land use/land cover mapping in Guinea. Specific objectives are:
- the assessment of the information content of optical and microwave data, considered separately;
- the assessment of the information content of a co-registered set of optical and ERS-1 SAR data.

3. TEST AREA PRESENTATION

The test area (centre coordinates 10°32' Latitude North, 9°20' Longitude West) is a 30 km x 30 km square located north of Kankan. It is crossed by the Milo River, a tributary of the Niger and includes the Bankalan watershed (182 km²), which was a site for an agricultural development project. The relief is flat or slightly undulating, with a mean elevation of 391 meters, a minimum of 355 meters and a maximum of 460 meters. The tropical climate is of sudanian type, with the rainy season from April/May to October. The mean annual rainfall for Kankan during the 1973-1984 period was 1411mm of which 92% fell in a 6 month period, thus limiting agricultural production. The main soils are Ferralsols, Fluvisols and Hydromorphic soils (FAO-Unesco Classification). "Bowal" soils are also found here with the upper horizon substituted by a lateritic crust and generally being associated with grassland savannah. On the 1:500 000 scale Forestry Map of Guinea (DNFC/BDPA/CTFT, 1989), the test area falls within the following categories:
- agricultural zone with intense clearings,
- tree savannah ("plus ou moins ligneuse"),
- mosaic of woodlands and tree savannah.

The region is characterised by environmental degradation due to bushfires and domestic fuelwood collection. Rice is the main agricultural crop and is cultivated in the wetlands, but productivity is low due to water shortage at the end of the cycle and low fertility on the hill slopes. Rice is also grown in the Milo flood plain where fields are prepared in order to extend the flood period. Figure 1 shows the location of the test area.

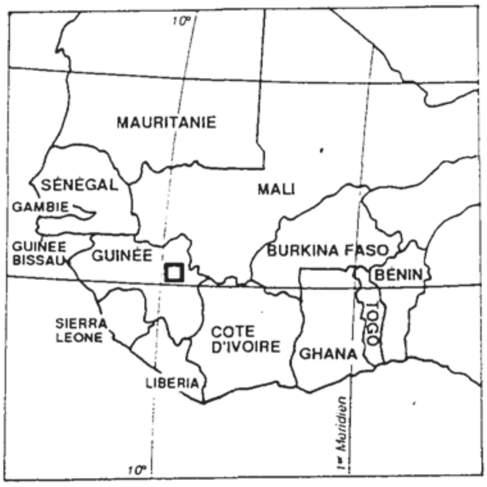

Fig.1: Test area location

4. DATA USED

This study was carried out using satellite data (microwave and optical), existing maps (topographic and thematic maps) and ancillary data. Table 1 gives the satellite data used. SPOT data of different dates were visually interpreted at 1: 100 000 scale (Full scene) and 1: 50 000 scale (Quarter scene). At the beginning of the project, ERS-1 SAR data used were Fast Delivery data (FDC), with 3-looks processing and

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a 20 m x 16 m pixel size. Later these data were reprocessed to slant range data, serving as input to the geocoding process. The ERS-1 data were acquired during the commissioning phase by the Maspalomas receiving station and then processed at ESRIN-Frascati. All the ERS-1 data were acquired during a descending orbit. In the first part of this project, special emphasis was given to the analysis of FDC SAR products as in the past data delivery delay has been identified as a limiting factor for operational use of remote sensing in agriculture and land use change detection. Landsat TM, SPOT XS (2 dates) and SIR-A data were acquired in October-November at the beginning of the dry season, or in March at the end of the dry season. ERS-1 SAR data were acquired in August-September during the rainy season.

Optically processed SIR-A data were digitized from a 1:500 000 scale film at 50 μm intervals (200 pixels per cm). The SPOT data had been preprocessed at level 1b which is adapted for thematic studies (500 meters RMS localization error in vertical viewing).
Ground truth data (field observations and photographs) were collected during visits to the test area in April 1991 and November 1992, i.e. during the dry season, after the end of the rice harvesting period.
The following maps were used:
- Vegetation Map, 1:5 000 000 scale (FAO-Unesco, 1981),
- Soil Map of the World, Africa Sheet, 1:5 000 000 (FAO-Unesco, 1973)
- Forestry Map, 1:500 000 scale (DNFC/BDPA/CTFT, 1989),
- UTM Topographic Maps, 1:50 000 scale (IGN, 1981).

The topographic maps had been recently updated using the JICA 1977-1979 aerial photo coverage at 1:100 000 scale and thus had a good accuracy. In addition, a 1: 15 000 scale land use map of the Bankalan watershed was available to check the observations from the satellite imagery. The latter had been produced (Kohl, 1992) from the interpretation of a non-controlled mosaic of false colour infra-red aerial photos acquired in October 1982.

SENSOR	DATE	PIXEL SPACING
SIR-A	14 Nov.1981	40m x 40m
Landsat TM	12 Dec.1988	30m x 30m
SPOT HRV	14 Nov.1986	20m x 20m
ERS-1 SAR	19 Aug.1991 28 Aug.1991 24 Aug.1991	20m x 16m (FDC) 20m x 16m (FDC) 20m x 16m (FDC)

Tab.1: Satellite data used

5. DATA PROCESSING AND GEOCODING

5.1 ERS-1 SAR data filtering

The visual perception and also the computerized analysis of SAR image data (e.g. standard digital image classification schemes) are both complicated by radar speckle, which is inherent to all SAR images. Generally, a homogeneous region with fully developped speckle (multiplicative noise) is statistically described by only one parameter, its mean value, which is directly proportional to the backscatter coefficient sigma. This implies that for the proper filtering process digital counts should be averaged within homogeneous regions, but in such a way that intrinsic textures, boundaries, linear features and bright pixels (corner reflectors) are preserved.
Several digital filters, e.g. Mean, Median, Edge Preserving Smoothing, Lee Sigma, Lee local statistics, Frost Minimum Mean Squaré, Li Adaptive Median and MAP (Gamma Maximum A Posteriori) were available and applied on the SAR image data. Some of the adaptive filters used, e.g. Frost Minimum Mean Square, Lee Local Statistics or MAP, need the coefficient of variation (CV) of "homogeneous regions" as input. CV is the ratio of standard deviation sigma per mean μ. Representative values are listed in Table 2. Histograms were drawn for each of the resulting filtered images and the following statistical parameters were computed: maximum value, minimum value, mean and standard deviation.

The filtered images were assessed visually, and in accordance with the statistical parameters it was found that adaptive filters, e.g. Frost Minimum Mean Square, Lee Local Statistics and MAP, give far better results than non-adaptive filters, e.g. Mean and Median which degrade the image content, especially the spatial resolution. The Frost filter was judged as one of the most suitable, because it smoothes homogeneous regions and keeps bright pixels. The more sophisticated and parameterized MAP filter was identified as a very useful filter for visual interpretation.

After observing that the best results were obtained with MAP and Frost filters for the specific objective of this study, i.e. visual identification of land use classes, two data sets of 1024 x 1024 pixels were compared:
- A) a subset filtered then rectified,
- B) a subset rectified then filtered.

In both cases, an EPS 5 x 5 filter and nearest neighbour method were used. A strong difference was noted between the two final images and the best interpretation results were obtained on A).

The analysis of the histograms confirmed that the radiometry of B) had been overmodified in relation to the original image. As a consequence of this observation, filtering techniques should be available before geocoding in a user-oriented SAR processing chain.

	Size (pixels)	CV = σ / μ
Test area	1024 x 1024	0.37776
Wetland	588	0.37242
River	76	0.36285
Flooded rice, begin.of cycle	614	0.31408
Savannah	1750	0.31513
Pond	136	0.35593

Tab.2: Coefficient of Variation (CV) of selected samples, 1024 x 1024 pixels, ERS-1 FDC, 19 August 1991

5.2 DTM production

The production of a Digital Terrain Model (DTM) and the geocoding of the satellite data were carried out by the Remote Sensing Laboratories of Zurich University. The DTM covers a 30 km x 30 km zone with a 30 meters grid. It was produced by digitizing 20 meters contour lines from 1:50 000 scale UTM topographic maps (IGN, 1981). Some of the contours were scanned but the rest including spot heights were digitized manually using ARC INFO ADS software (Arc Digitizing System). The DTM was produced using the ARC INFO TIN software (Triangulated Irregular Network).

5.3 Optical data geocoding

Difficulties were encountered during the Landsat TM data geocoding in identifying Ground Control Points (GCP) in this savannah zone with very few villages and cross-roads. In addition the Milo Valley is periodically flooded. The Map/Image GCP selection was therefore difficult. Forty-one GCPs were initially selected. After elimination of GCPs with a high residue, 23 GCPs were finally used for the transformation coefficients calculation (least square method). The 23 GCPs give the following statistics:

mean residue (Column direction)	0.47 pixel
mean residue (Line direction)	0.31 pixel
RMS error	0.69 pixel

Image correction and resampling (1000 x 1000 pixels) were performed by cubic convolution. The relative accuracy of the geocoding was verified by superimposing TM band 4 on the original maps and was considered satisfactory. The two SPOT images of 1b level were interpreted without geocoding.

5.4 Optical data/ERS-1 SAR data registration

In order to register the SAR data with the already geocoded Landsat TM data, 5 homologeous points were selected in both data sets. The affine coordinate transformation showed a total RMS error of 1.89 pixel in the SAR image. This good result is due to the fact that the points were selected along the river (more or less the same height). In the hilly region the SAR geocoding should be done with rigorous radargrammetric methods using a high-resolution DTM. The relief induced geometric distortion is 23.6 meters (more than 1 pixel)in range direction for every 10 meter height difference at mid-range of an ERS-1 scene. Therefore, precise terrain correction of ERS-1 SAR data is an essential pre-requisite for georeferenced data analysis. Relief distortion = delta Height difference * cot(incidence angle). ERS-1 SAR data were geocoded in the second part of this project (see section 5.5).

5.5 ERS-1 SAR data geocoding and post-processing

The following tasks were performed:

- speckle reduction, using the Minimum Mean Square Error Filter (Frost et al., 1982).

- high precision geocoding. Through a complete reconstruction of the imaging geometry, taking into account processor characteristics, the primary topographic effects (foreshortening, layover) as well as the influence of earth rotation and terrain height on the doppler frequency shift and azimuth geometry are calculated (Meier et al., 1989). Nearest neighbour resampling method was choosen with a pixel spacing of 30 meters, as the DTM and Landsat TM data.
The following problems were encountered during the SAR geocoding process:
a) limited map coverage (50% in the range direction) with DTM coverage less than 30% of the imaged swath,
b) 15 years period between map generation and image acquisition,
c) difficulty to identify GCPs in this savannah zone.

- relief induced radiometric correction using a backscattering model based on the local incidence angle.

- texture analysis applying second order statistics. The Spatial Gray Level Dependence Method (SGLDM) was used (Haralik et al., 1973). It is a statistical method based on a moving window technique (7 x 7 pixels) that computes texture features (Sum average, Contrast, Variance, Entropy) from the probability of going from gray level i to j, with a given intersample spacing and considering 4 directions: 0°, 45°, 90°, 135°.
In this specific study, the production of textural files did not improve the identification of land use classes. Texture analysis is based on the fact that an important factor for the dicrimination of natural features is the tonal information, i.e. the local mean intensity of the radar backscatter. Textural features based on second order statistics indicate that the texture information content in low spatial resolution images is very low. Due to the frequency of ERS-1 (C-band), the tonal variation between different scatteres is very limited. In the special case of vegetation identification, this results in a poor discrimination of the local tonal information.
In addition, the textural information in the FDC and PRI images is also reduced because of multi-look processing and resampling to pixel spacing of 12.5 m x 12.5 m. This resampling procedure gives rise to autocorrelation between pixels. The degree of autocorrelation varies depending whether we consider the near range or the far range. The autocorrelation is slightly higher in near range than in far range because of slant to ground range conversion of data.

Fig.2 presents the post-processing steps of ERS-1 SAR data.

6. DATA ANALYSIS

Digital data were analysed on an Erdas System (7.5 Software version) and a Pericolor 2001. The objective of the digital processing was to produce enhanced optical data, SAR filtered data and optical microwave combinations for visual interpretation. This approach was considered being better adapted to future operational mapping projects for the following reasons:
- FAO Remote Sensing Centre's experience and present activity in the field of thematic cartography using optical satellite data.
- limitations of statistical classification of optical/SAR digital data already observed in a previous study carried out in Tunisia (Lichtenegger et al., 1991).

6.1 Visual interpretation of optical and microwave data

The visual interpretation of the satellite data was performed mainly using 1:100 000 scale photographic enlargements from standard film. Complementary observations were done on a 1:50 000 scale SPOT XS print (Quarter scene) and on digitally enhanced products. SPOT XS and Landsat TM data were acquired during the dry season. Using SPOT XS 3/2/1 and Landsat TM False Colour composite 4/3/2 it is possible to delineate riverine forests and therefore the drainage pattern of the zone; one can also identify temporary ponds, roads, villages, burnt areas and agricultural zones, savannah zones. On SPOT XS data of 14 November, it was possible to differentiate between late rice in the Milo flooding plain and rainfed rice already harvested due to the strong reflectance of soil and straw residues. Satisfactory results can also be obtained from the interpretation of Landsat TM 4/5/3, especially for the delineation of moist zones.

ERS-1 SAR images were acquired during the rain season (19 August, 28 August and 24 September) which is also the period of maximum cloud cover. The visual interpretation of non-filtered data gives very poor results due to the presence of speckle and should be avoided. On SAR filtered data (MAP), using single date acquisition, it is possible to identify agricultural zones but without separating flooded rice from rainfed rice or other crops. There may be some confusion between agricultural zones with high backscatter and villages. It has not been possible to delineate the drainage pattern as riverine forests do not appear. Results improve significantly in the case of a multitemporal approach and a colour combination of the three dates displayed in red, green, blue. In this case the eventual confusion between agricultural zones (high dynamic) and villages (low dynamic) disappears. There is a very strong difference in the radar backscatter of flooded rice between 19 August (high backscatter), 28 August (low backscatter) and 24 September (low backscatter). If on the first date crop/water interactions are present, on the following dates, due to the growth of the rice and to the limited radar penetration, only the backscatter component from the upper layer of the crop is observed. At the date of 24 September, the low backscatter is explained by the fact that the flooded rice was temporarily under submersion, thus a specular reflection from the water surface was observed. These observations are in accordance with the evolution of irrigated rice crop radar backscatter observed during the crop cycle using airborne radar data in the

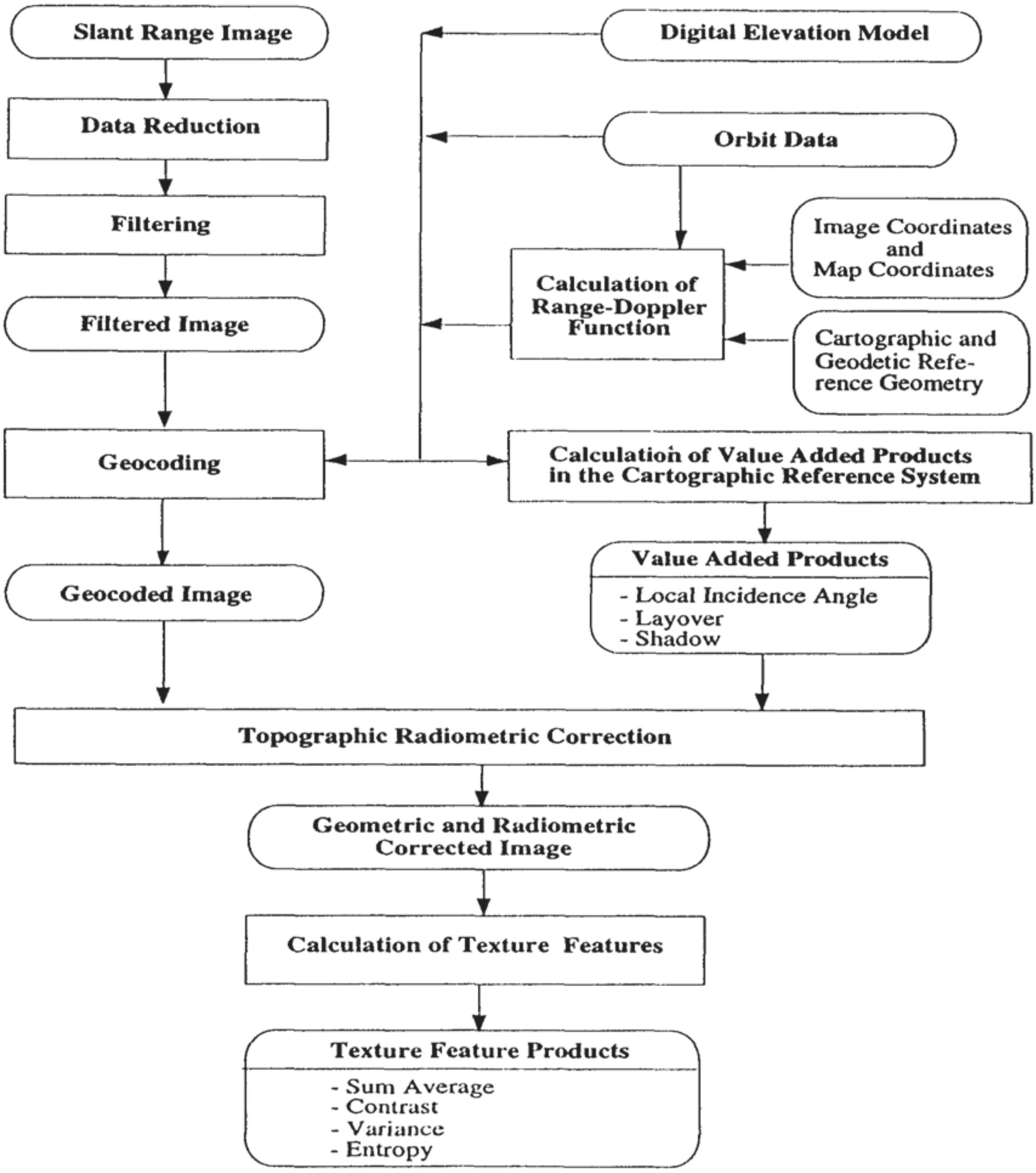

Fig.2: ERS-1 post processing steps (from Schmidt, 1993)

Camargue (Laur, 1989). Therefore, using spaceborne optical and radar data, it becomes easier to differentiate flooded rice from other crops; for example, the agricultural field pattern can be extracted from dry season SPOT XS data and information on the presence/development stage of the rice crop can be extracted from ERS-1 SAR images. On the multitemporal SAR image of Bankalan it is also possible to delineate the extent of the flood of Milo River and the temporary ponds.

A visual comparison was done between ERS-1 SAR FD image and SIR-A 1:100 000 scale paper print. The time period of 10 years between the two radar image acquisitions is a limiting factor, although in this zone the landscape does not vary much from year to year; the seasonal variations are more marked. SIR-A image was considered to have a poor information content due to optical processing and 40 meters spatial resolution. Nevertheless, riverine forests appear clearly on L band SIR-A data and can not be detected on C band ERS-1 data. This confirms the usefulness of L band for the separation of land use classes and stresses the usefulness of future joint ERS-1/JERS-1 SAR data acquisitions.

6.2 Integration of Optical and SAR data

Two methods of merging these complementary data sets were tested in this study.

- In the first case, a colour composite Red/Green/Blue as SPOT 3/SPOT 2/ERS-1 SAR was produced, i.e. a false colour composite in which the SPOT 1 band (green component of the electromagnetic spectrum) was substituted by the respective radar image data. The visual interpretation of the various false colours enables a correlation between properties of the surface and its response on microwave/optical data, e.g. yellowish colours correspond to surface elements with intermediate reflection in NIR and red, and also low SAR backscatter: this is the case for example of areas with a low vegetation index and a smooth surface. Such areas were identified as sand-banks and some agricultural zones along the Milo river.
- In the second case, the method for merging multisensor image data using a Intensity-Hue-Saturation (IHS) transformation was applied. The infrared false colour composite was transformed from RGB colour space into the IHS colour space, where the intensity component was substituted by the SAR image data. Finally, this new image was transformed back to the original colour space. The advantage of this method is that it combines radar backscatter values with spectral information of 3 optical bands. Classical image interpretation can be appied, i.e.: bright reddish colours correspond to high backscatter (rough surface) with high vegetation index, dark ones to low SAR backscatter (smooth surface), respectively.

In order to check and validate the observations, the existing 1:15 000 scale land use map was digitized. This land use map was produced from the interpretation of 1: 15 000 scale Infra red aerial photographs (Kohl, 1992). Even if the geometry of this non-controlled mosaic was not satisfactory, it allowed the interpreters to check and validate their observations. The following thematic classes were choosen and digitized: river, flooded rice, wetland rice outside flood plain, water saturated zone, crops other than rice, villages, savannah.

6.3 Elements of cost

It is important to establish the difference between operational and experimental satellite remote sensing missions. Seasat (1978), SIR-A (1981), SIR-B (1984) are examples of successful microwave experimental missions while Landsat (since 1972) and SPOT (since 1986) are examples of well succeded optical operational missions. In order to separate experimental missions from operational missions, the following criteria have to be investigated:
- information content of the data with respect to thematic applications,
- data availability in terms of spatial coverage of the earth,
- data availability in terms of access to historical data and continuity of the data supply,
- data delivery delay between order of the images and their reception by the users. Programming time must be taken into account. Data delivery delay must be clearly distinguished from processing time. It should be noted that the useful information for the users is not the minimum delivery delay that can not be used during mapping projects formulation but the maximum delivery delay that is one of the inputs required to define a project time table.
- price per km² and data distribution policy.

Remote sensing data users in the field of natural resources mapping can work mainly on the extraction of thematic information and make recommendations about data availability and data delivery delay. In addition, they may compare the cost of execution of a mapping project based only on optical data with the cost of a project based on complementary optical/microwave data. Such a comparison was done considering the Land use/Land Cover Map of Afghanistan (FAO Remote Sensing centre, 1992/1993).

The objective of this project presently under execution is to produce a Land Use/Land Cover Map of the entire Afghanistan (647.451 km²) at 1:100 000 scale, and also to produce 82 spacemaps at 1:100 000 scale. This area is covered by 43 Landsat TM scenes.
The cost of the remote sensing component, including map printing and 10 copies of 82 spacemaps, is US$ 1.486.000, i.e. US$ 2.2/km². The total cost of the project, including the remote sensing component and the creation of a digital data base is US$ 2.200.000, i.e. US$ 3.3/km².
The manpower associated to the project activities is 22.5 person/month for the analysis and interpretation of satellite data, 24 person/month for the cartographic work and 25 person/month for the data base creation.
Additional costs related to a hypothetical integration of ERS-1 SAR data in such a mapping project were computed. The methodology choosen for this estimation consists of visual interpretation at 1:100 000 scale of Landsat TM images and ERS-1 Precision images (2 dates). The following costs were considered:
- ERS-1 data, 800 Ecus/scene of 100 km x 100 km, i.e. US$ 0.19 per km²,
- ERS-1 filtering and ERS-1 registration, 2 computer days (US$ 500/day) per scene, i.e. US$ 0.10 per km²,
- ERS-1 film production (US$ 380) and photographic enlargement (US$ 120), i.e. US$ 0.05 per km².

The total additional cost related to the use of ERS-1 data is thus US$ 0.34 per km². For a country like Afghanistan, if we consider that high mountains and deserts should not be covered by ERS-1, and that SAR acquisitions should only cover half of the country, the additional cost is then US$ 110.160, i.e. 5.5% of the project initial budget.
It should be noted that these figures are computed assuming:
- no terrain correction of SAR data using a Digital Elevation Model,
- no mosaïquing of ERS-1 scenes.

It should also be noted that if it is relatively easy to compute the costs of execution of a mapping project (satellite data, manpower, equipments), it is extremely difficult to quantify the long term benefit for the country of map production activities.
It appears nevertheless with this example that the present level of cost of ERS-1 SAR data is not a limiting factor for an operational use of spaceborne radar imagery.

7. CONCLUSIONS

ERS-1 Terrain corrected but also Fast Delivery SAR data were found useful for land use/land cover mapping purposes in the Bankalan test area which is a savannah zone with rather flat topography and agricultural activity. Despite their radiometric and geometric limitations, ERS-1 FD SAR data were

considered as satisfactory due to:
- data delivery delay,
- information content especially concerning flood extent quantitative assessment, rice crop identification and monitoring, water saturated zones and temporary ponds identification.
For thematic purposes in this rather flat zone (105 meters height difference in a 30 km x 30 km square), it was possible to register ERS-1 SAR FDC image to an optical image taken as reference without SAR geocoding. Nevertheless, for land use/land cover mapping, interpretation of the monospectral ERS-1 FDC data did not provide satisfactory results in the case of a single date interpretation. Problems were encountered for riverine forests identification on ERS-1 data but not on L-band SIR-A images.

Better results were obtained by registration of 3 ERS-1 SAR images in a multitemporal approach, and to a greater extent in the case of combined analysis of ERS-1 SAR data with SPOT XS and Landsat TM optical data. In this latter case, ERS-1 SAR data allow the interpreter to improve visual interpretation keys, especially using dry season optical data and wet season radar data. In all cases, (SAR monotemporal, SAR multitemporal, SAR and optical data) ERS-1 SAR data had first to be filtered with an adaptive filter in order to reduce image speckle.

For vegetation mapping at 1:100 000 and 1:50 000 scale, SPOT XS and Landsat TM data are a valuable operational tool due to the possibility of delineating vegetation classes, and eventually density or biomass categories. In this study, it has not been possible to detect on ERS-1 SAR images a progressive degradation of vegetation cover or to separate tree savannah/woodland/riverine forest. Moreover, ERS-1 SAR images presented some limitations for vegetation classes mapping but these radar data were found useful to assess seasonal variations of land use. There is a strong complementarity between the information content of SPOT XS or Landsat TM and ERS-1 SAR data, especially in the field of moist zones detection, flood extent mapping, rice/irrigated crops identification and monitoring, as well as for deforestation assessment (defined as passage from forest to bare soil or pasture). In this specific project, it appeared that the additional cost of terrain geocoded SAR data was not justified and that satisfactory results could be obtained with ERS-1 FD products. For future operational projects of land use/land cover mapping in cloud prone areas, the combination of multitemporal ERS-1 data with an existing SPOT XS image, even archived, is very promising.

8. RECOMMENDATIONS

Based on the observations of this land use/land cover mapping study, the following are recommended:
-ERS-1 SAR image data: the possibility to have ERS-1 SAR image data filtered on request using adaptive SAR filters at the Processing and Archiving Facilities, prior to image geocoding.
-the presentation on tape of ERS-1 SAR FD image data with pixel (1,1) associated to the North-west corner of the scene, as in the case of SPOT and Landsat, independantly of ERS-1 SAR acquisition in an ascending or descending node. Since one single ERS-1 SAR FDC image corresponds to 60 Megabytes and as there is a growing use of PCs with limited memory capacity for image processing, this would eliminate the need for the image rotation by the user and would make data integration more straightforward.
-the possibility to require, for specific zones, ERS-1 SAR image quick-looks, in analog or digital format.
-experiments: development of controlled data bases in selected zones including Digital Terrain Model, optical data (SPOT XS and Landsat TM) and SAR data (C-band ERS-1, L-band JERS-1, S-band ALMAZ) for environmental thematic studies.
- development of experimental work on SAR image analysis for land use/land cover mapping, soil moisture monitoring, tropical deforestation, irrigated/flooded crops identification, flood extent mapping.
-future missions: the inclusion for future missions of on-board recording capacity for SAR image data in order to reduce the dependance on the existing receiving stations.

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