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N10

THE INVENTORY AND MONITORING ROLES OF SPOT XS DATA FOR PLANTATION FORESTRY MAPPING

LES ROLES D'INVENTAIRE ET DE CONTROLE DES DONNEES SPOT XS DANS LA CARTOGRAPHIE DES PLANTATIONS FORESTIERES

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ABSTRACT

Plantation crops have the potential to provide optimal spectral signatures for satellite mapping. Normally such crops are present as a uniform unit area. Usually within a unit they are characterised by uniform age, uniform canopy, often uniform height, uniform plant geometry, uniform biomass and uniform management practice. Spectral irradiance is a relatively "pure" value with a minimum of mosaic contribution. Theming process is optimised.

Establishing an inventory of different crops, and different age classes based on characteristic spectral signatures is tested. Any changed management practice, physiological stress, pathological factors, phenological patterns, seasonal growth regimes, harvesting, etc can be assessed by subsequent satellite monitoring showing departures from the standard spectral signatures.

Examples are discussed.

RESUME

Les cultures de reforestation ont la particularité d'offrir des signatures spectrales pour la cartographie par satellite. Normalement, de telles cultures se présentent comme

une zone d'unités uniformes. Généralement, au sein d'une unité, elles sont caractérisées par un âge uniforme, une voûte uniforme, une hauteur souvent uniforme, une géométrie uniforme des plantes, une biomasse uniforme et des pratiques de gestion uniformes. L'irradiance spectrale est une valeur relativement "pure" avec un minimum de contribution hétérogène. La reconnaissance thématique est optimisée.

L'on essaye d'établir un inventaire des différentes cultures et classes d'âge à partir des signatures spectrales caractéristiques. Toute modification dans la culture, le stress physiologique, le facteur pathologique, le modèle phénologique, le régime de croissance saisonnière, la récolte, etc. peut être évaluée par contrôle satellite ultérieur faisant apparaître des modifications par rapport aux signatures standards.

Des exemples illustrent ces propos.

INTRODUCTION

Formal European settlement of New Zealand began in 1840. Vast areas of the predominantly forested land were cleared in the ensuing decades and planted with exotic grasses and clovers.

Early economic dependence upon exploitation of the indigenous forests for timber soon gave way to a predominantly pastoral economy. One hundred and fifty years later although the economy has a broader base pastoral activities still represent the major part of the country's economy. Large areas of the central area of the North Island, composed of a wide range of volcanic rocks and veneered with layers of pyroclastic ash falls, when cleared of forest and planted to grasses could not support healthy stock. Several decades later it was discovered that a cobalt deficiency in the soils was the cause of the so called "bush sickness" of stock on these volcanic soils.

As a consequence in the decades of the 1920s and 1930s these "unfavourable areas" considered not suitable for stock grazing were planted with Monterey pine (Pinus radiata) and Ponderosa pine (P. ponderosa). The P. radiata plantations thrived, growing much more rapidly than in their home environment in California. Conversely Ponderosa pine displayed slow growth. Douglas fir (Pseudosuga menziesii), other Pinus spp. and several species of broadleaf hardwood, Eucalyptus spp. were also planted later.

Subsequently major planting programs, primarily of Radiata pine, were implemented and an important timber industry developed. Today New Zealand has the largest area of planted conifer plantations (over 400 000ha) of any country in the world. Most of this area is concentrated in the central volcanic plateau of the North Island.

Both the State owned and the privately owned sections of New Zealand's exotic forestry industry have developed very efficient silvicultural management and operation techniques. Forest units are typically single species, uniform age stands. Planting, growing, thinning, felling and replanting procedures follow a 15-25 years sustained yield cycle depending upon whether pulp or timber is to be the end product.

Although forest management is well recorded by means of field surveys and aerial photography the advent of data available from resources satellites such as LANDSAT and SPOT provides improved potential for inventory purposes and particularly for efficient, rapid and cost effective monitoring of management change.

Studies in Sweden (Jaakkola, 1988 ; Jaakkola et al., 1988), Finland (Häme et al., 1988), Carolina, U.S.A. (Brockhaus et al., 1988) and Australia (Turner et al., 1988) all suggest that such satellite data can provide important contributions for inventory and management roles in commercial forestry.

SPOT data were used for testing a wide range of classification applications and monitoring of patterns of disturbances in Polish coniferous forests by Bochenek et al., (1988).

Costs of both LANDSAT Thematic Mapper (TM) and SPOT data are about 1- 2 percent per unit area (km2) of the cost of vertical aerial photography. The problem of the guaranteed acquisition of satellite data is the only uncertainty for their operational use in forestry. The SPOT satellite has an important advantage over LANDSAT in this regard because of the off-nadir viewing and hence more frequent revisit capability of the French satellite. For much forestry application the higher spatial resolution of SPOT data is an added advantage. Agatsiva et al., (1988) commend this high spatial resolution of SPOT for forest studies in Kenya.

METHODS

Multitemporal data from LANDSAT MSS and SPOT XS have been used for mapping exotic forests in part of the Kaingaroa forest in central North Island. A subscene from a LANDSAT II image (E-2334-21123) of central North Island taken on 22 December 1975 was contrast enhanced to produce a simulated colour infrared colour composite (Bands 4, 5, 7 : B, G, R). Forestry patterns were mapped from this based on visual analysis of spectral signatures (colour tones). These were compared with a New Zealand Forest Service map of 1975 showing distribution of forest species by forest compartments.

A similar subscene of the same area taken from a SPOT I image (444/427) of 5 August 1986 was also contrast enhanced to produce a simulated colour infrared colour composite (XS1, 2, 3 : B, G, R). Forestry patterns were again mapped by visual analysis of tonal contrasts. The results were then compared with the LANDSAT data of eleven years earlier.

Selected field checking of the SPOT patterns has been carried out. Patterns mapped have been compared to 1986 forestry records where these have been available.

This visual analysis of the image data enlarged to 1:250 000 scale represented an encouraging first stage in an ongoing research program. Following these successful first stage mapping analyses, smaller subscenes were then enlarged to 1:100 000 scale and again analysed by visual interpretation of colour tones. These are shown as colour figs. N10A and N10B.

Having established the validity of the concept future research will focus on digital processing using digital spectral values for computer mapping. Establishment of a range of indices of management will subsequently be incorporated for GIS applications for the better merging of the SPOT spectral data to forestry/landscape planning and management (Patera and Cochrane, 1990). Additionally the analysis procedures will be tested for forests on physically more diverse landforms and where neat geometric patterns are not present.

RESULTS AND DISCUSSION

The mid-Kaingaroa forest area analysed in the LANDSAT and SPOT subscene images represents an optimal testing site for mapping of plantation forestry. In addition to the general characteristics of uniformity of various vegetative aspects that typify exotic conifer plantation forestry in New Zealand this area has large simple geomorphic units. Forests occur on a relatively flat plateau surface with uniform soils. There is minimal dissection. New Zealand's exotic conifer plantations are managed tree crops that provide optimal spectral irradiance signatures for mapping from satellites. Because such tree crops are present as moderately large, vegetatively uniform unit areas, spectral irradiance is a relatively "pure" value with a minimum of mosaic contribution. Inspection of colour figs. N10A and N10B clearly demonstrates these qualities. This is in direct contrast to the complex mosaic spectral composition of indigenous forests characterised by varied structure and complex species composition. Usually within any exotic forest unit they are characterised by all the following : uniform age, uniform canopy characteristics, often uniform height, uniform plant geometry, uniform biomass, and uniform silvicultival management practice (colour fig. N10C). Theming and classification processes are optimised when mapping such data.

Mapping of boundaries between different spectral "cells" was facilitated by the geometric patterns and usually a prevailing uniformity of cover class representing a specific silvicultiral management stage within most of the forest compartments that characterises the mid-Kaingaroa forest region (colour figs. N10A, N10B and N10C).

Recognising these characteristics an inventory of different types of tree crops, different age classes and stages of felling, clearance and replanting were mapped from the LANDSAT MSS data (colour fig. N10A). Mature forests of the two major forestry species Pinus radiata (Monterey pine) and Pseudosuga menziesii (Douglas fir) are readily recognised from their spectral signatures recorded as colour tonal variances on the images. See also colour fig N10C. Mature Pinus nigra and P. ponderosa (Ponderosa or yellow pine) forest stands also have distinctive characteristic tonal properties. Very old (over 50 years) stands of P. radiata could not be easily separated from the younger and mature under 30 years old stands of the same species from the LANDSAT image. Young Douglas fir has a different spectral signature from mature stands but it is not readily recognised on the LANDSAT image. Stands of mixed species including the conifer P. contorta and several Eucalyptus species (hardwoods) are difficult to separate from P. nigra on spectral signature alone. Clear fell, burned areas, and very new plantings are all clearly identified by distinctive spectral tones (colour fig. N10A).

The same area was mapped from SPOT XS data recorded nearly eleven years later (colour fig. N10B). Compiling an inventory of forestry species was more readily achieved using this SPOT XS 1986 data. The improved spatial resolution from the 80 metres of the LANDSAT MSS to the 20 metres of SPOT XS plus the increased spectral range of SPOT data facilitated the mapping process. Old P. radiata can be separated from mature and younger stands. Differentiation of Douglas fir stages is more readily mapped with the SPOT data. Table 1 summarises landcover classes, with their descriptive colour tones and MUNSELL colour classifications for the SPOT XS data.

Mapping the same area almost eleven years after, using the SPOT XS data shows the value of the multitemporal role for recording changes. Compare colour figs. N10A and N10B. Figure 2 summarises total change over the ten and a half year period. It demonstrates the dynamic managed nature of these intensively utilised forests. This figure shows that 53 of a total of 221 forest compartments are the only areas that have not undergone major forest management change during the decade between late December 1975 and early August 1986. Comparison of the LANDSAT and SPOT subscene images show some former exotic forest areas have been cleared very recently, and some less recently that are now in early stages of regrowth. Other readily observable changes are former cleared areas of 1975 now in various stages of regrowth. Each land cover type has a distinctive spectral tone. Differences in age, reflected in extent of canopy crown closure, are among the more subtle spectral signature variations in the recently replanted areas. See colour figs. N10B and N10C.

Classification of all the forest compartments has been mapped for the area of colour figure N10B. These are not all reproduced, however, in figure 1 as this would make a very detailed complex map. Instead figure 1 portrays some selected examples of different forest species, a range of different age stands of P. radiata, recent replantings and cleared areas. Table 1 provides summary data of the mapped cover classes. Comparison of colour figs. N10B, N10C andfig. 1 with Table 1 indicates clearly the distinctive colour tones that are representative of the various forest plantations and associated management cover classes.

Crop calendar phenological patterns and seasonal growth regimes readily monitored on many annual field crops do not find expression in perennial exotic conifer plantations.

However, any changed management practice such as felling, clearing, replanting, trimming or thinning is readily monitored, as each has a distinct spectral signature (Turner et al., 1988). Additionally, changes due to causes such as physiological stress or pathological factors can be assessed with satellite monitoring as these would show as departures from the standard spectral signatures (Bochenek et al., 1988). Major stages of planting recognised by Forestry companies operating in the mid-Kaingaroa area fall into broad groupings. These are 1) pre 1941, 2) 1941-1960, 3) 1960-1985, and 4) post-1985. Forests representative of these categories can be recognised from the spectral signatures on the SPOT XS subscene image. Some categories can be derived from the SPOT XS data alone (colour fig. N10B and figs. 1 and 2). Mapping of other categories of landcover are facilitated by multitemporal comparisons with the coarser resolution LANDSAT MSS earlier image of 1975 (colour fig. N10A).

Similar criteria for monitoring should apply to other exotic conifer plantations such as those at Drasa, Lewa and Nandarivatu in Western Viti Levu, Fiji's largest island.

SUMMARY

LANDSAT MSS data is useful for generalised mapping of New Zealand exotic forest plantations. It is difficult, however, for detailed mapping without weighted enhancement techniques. Even for the large relatively uniform forestry stands the 80 metres spatial resolution provides limitations to classification.

LANDSAT TM should provide more accurate mapping than M.S.S. data. To date no TM data of the forest areas of New Zealand have been acquired. Encouraging results, especially with use of the TM bands 5 and 7, have been recorded by Bazire et al., (1988), Brockhaus et al., (1988), and Guyon and Rion (1988).

SPOT XS data are excellent for both inventory and monitoring roles for New Zealand exotic forest mapping applications. They are much superior to LANDSAT MSS. Much of this improvement results from the 20 metres spatial resolution of SPOT XS data.

In the mid-Kaingaroa forest test area, analysed as a SPOT colour composite image in this paper, forest stands of all major tree species can be recognised by their distinctive colour tones.

Different age classes can be identified. Additionally stages of young regrowth, areas of replanting and cleared areas can all be mapped from visual analyses of spectral tones on imagery enlarged to 1:25 000 to 1:100 000 scales.

This survey has been confined to visual analyses but multitemporal data coupled with digital classification provide a potentially rapid and economic tool for many aspects of forestry mapping and monitoring of management patterns.

The large area uniform units of plantation forestry provide optimal spectral cells for mapping from satellites.

It is believed that the techniques will be practical though less easy for plantation forestry mapping in physically more diverse areas with irregular patterns of forests.

The results from this analysis of coniferous plantation forestry in central North Island, New Zealand demonstrate that SPOT data are a useful tool for inventory and management roles.

The conclusions presented by Jaakkola in his review paper (1988) are confirmed in this study.

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TABLE 1

GROUND COVER CLASSES SPOT 1 XS KAINGAROA

	Cover class	Colour tone	* Munsell colour classification
I.	**BARE GROUND:**		
	1. Recently cleared (Clear fell)	Cyan (light bluish grey)	5 B 8/1
	2. Recently cleared (burned and scrub)	Bluish grey	5 B 6/1
	3. Loading areas	Light bluish grey	10BG 8/1
II.	**FORESTS:** (exotic species)		
	1.a. Pinus radiata - recently planted (young)	Light reddish grey to reddish grey Light reddish grey	7.5R 7/2, 6/2 10 R 7/2
	b. P. radiata - established (10-20 years)	Grey reddish brown Dark red	10 R 4/4 10 R 3/6
	c. P. radiata - mature (to 30 years)	Red	7.5R 4/6
	d. P. radiata - very old (over 50 years)	Greyish red	7.5R 4/4
	2. Pinus nigra - mature	Blackish red (Dark black brown)	7.5R 2/2
	3.a. Pseudosuga menziesii - (young)	Bright reddish orange and red	10 R 6/8
	b. P. menziesii - (mature)	Dark red (dark brown)	7.5R 5/6 to 6/8 7.5R 3/4
	4. Other plantation spp. (Pinus contorta and Eucalyptus (hardwood) spp.	Dark reddish brown	10 R 3/1
**	**FORESTS:** (indigenous)		
	5.a. Mixed podocarp - broadleaf (native bush)	Brown reddish black	10 R 4/2
	b. Broadleaf beech (Nothofagus spp.)	Black reddish brown	10 R 3/1
	6. Pasture	Orange, pinks and lighter tones	7.5R 7/8

* Munsell tones are from the SPOT photographic products used in mapping. They may not reproduce exactly the same in the printing of figure 2 for this paper.

** Not present on the 1:100,000 subscene image. Mapped from 1:250,000 subscene analysis.

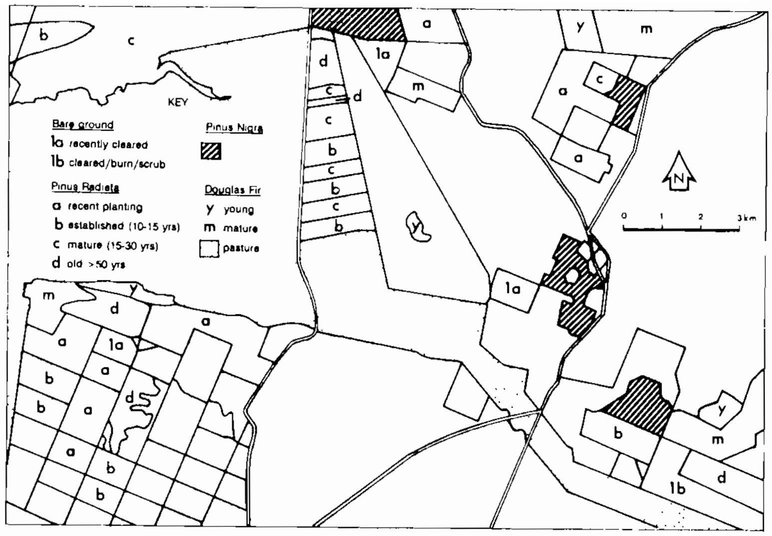


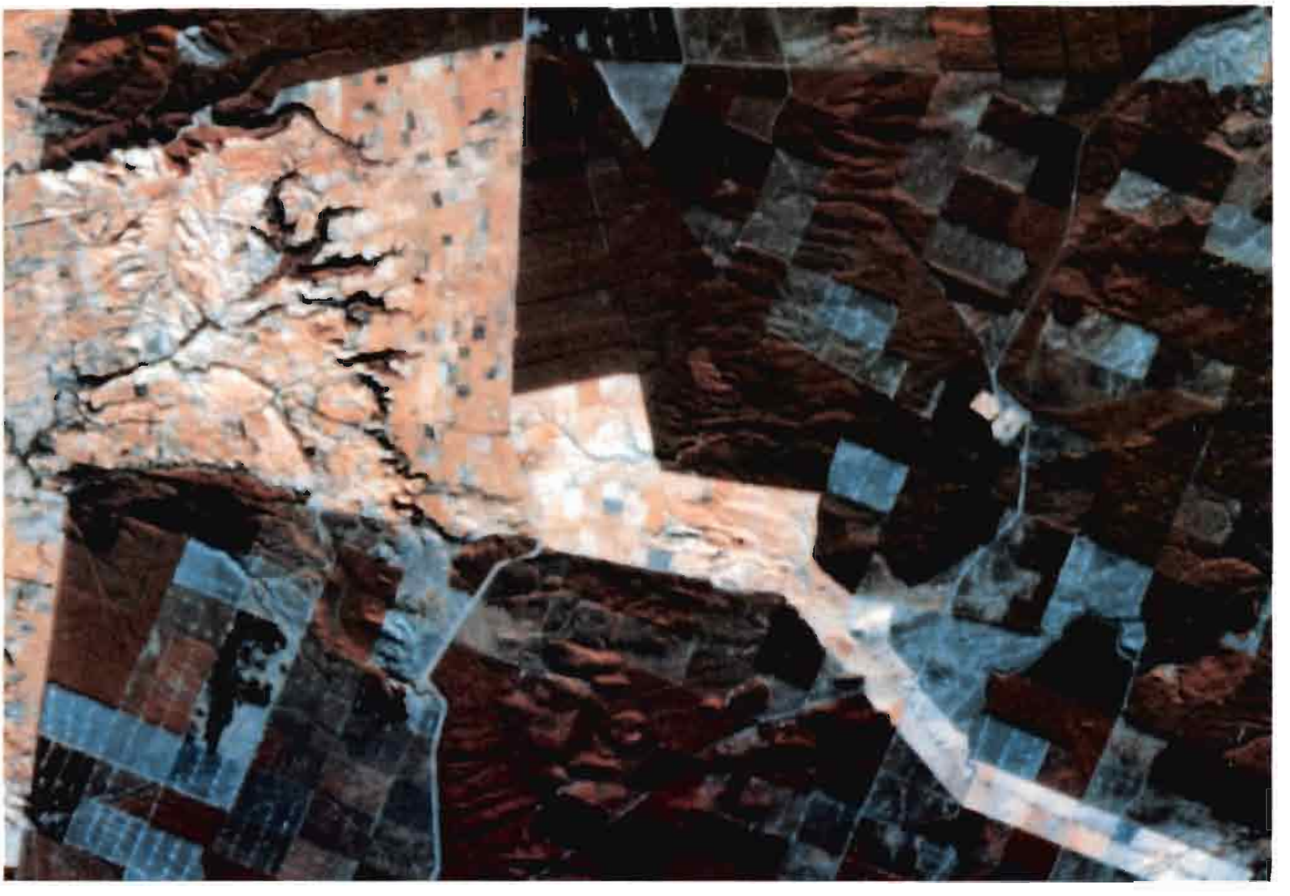
Figure 1 : Mid-Kaingaroa forest. Classification of the forest compartment obtained from SPOT XS data (see colour fig. N10B.)

Figure 2 : Mid-Kaingaroa forest. Mapping change by comparison of Landsat and SPOT data respetively 22/12/75 and 5/8/86 (see colour N10A and N10B)

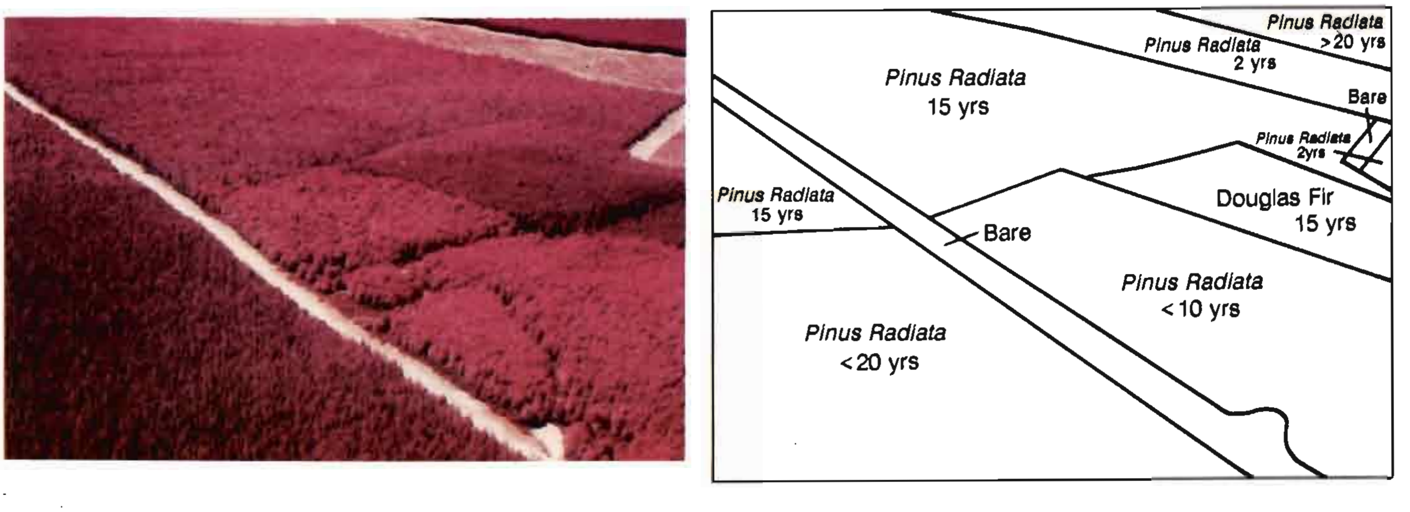
N10

N10A : Central North Island Mid-Kaingaroa forest. Enlarged subscene (1/100.000) from LANDSAT II 22/12/75.

N10



N10B : Central North Island Mid-Kaingaroa forest enlarged subscene (1/000.000) similar to colour fig. N10A from SPOT 1 5/8/1986. c CNES 86/dist. SPOT IMAGE.



N10C : Mid-Kaingaroa forest. Left : aerial view ; right : corresponding legend.

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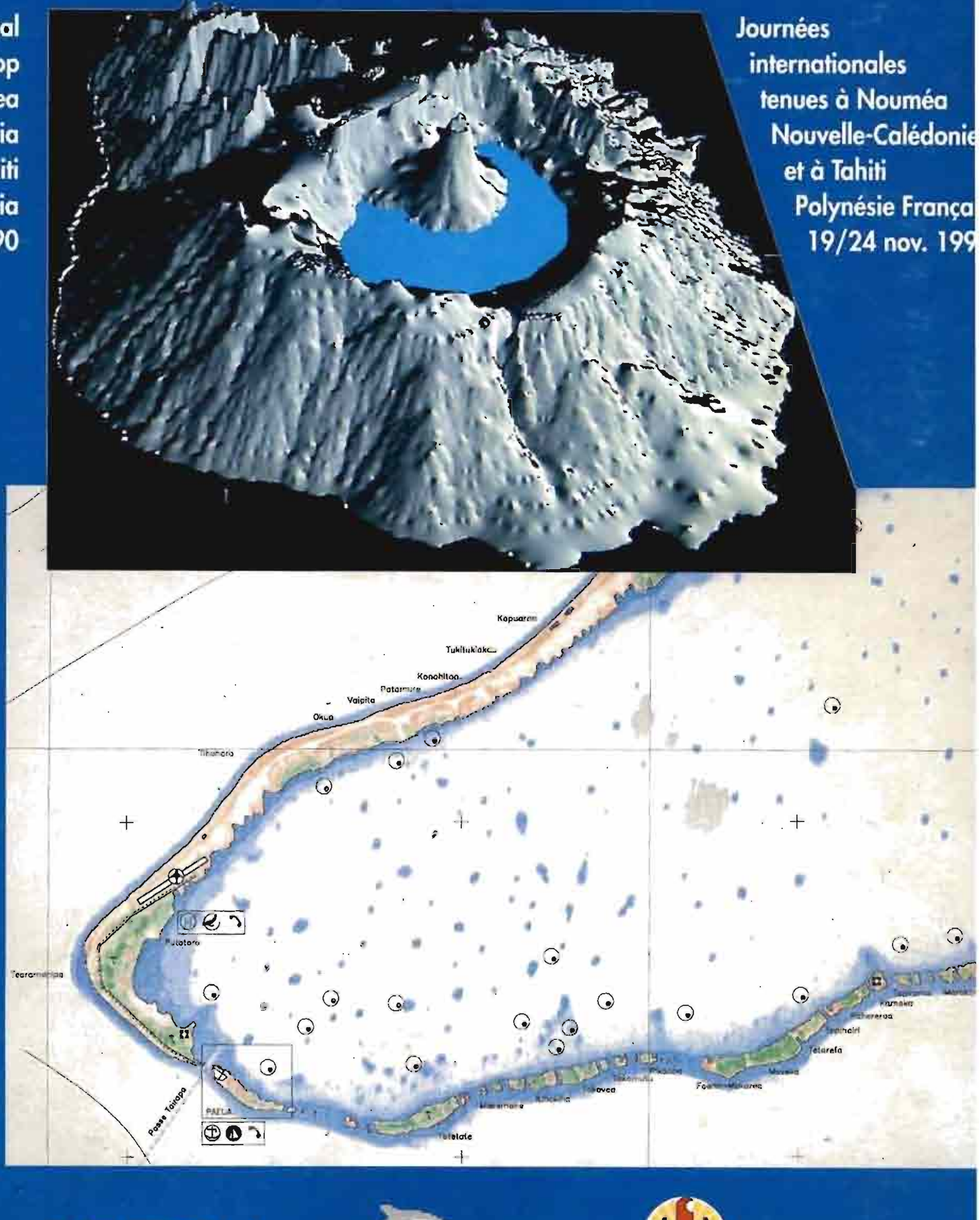

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