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THE ROLE OF SPOT FOR MAPPING INTENSIVE SMALL CROP/HORTICULTURE

ROLE DE SPOT POUR LE CONTROLE D'ACTIVITES HORTICOLES INTENSIVES

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ABSTRACT

One of the prime objectives of the SPOT system is to improve the capability of conducting resource analyses of small area agriculture from space.

This paper investigates the role of SPOT for monitoring small crop/horticultural activities. It addresses the spectral/areal relationships of dispersed cropping with adjacent land cover/land use classes and the role of scale. Examples used are from N.Z. SPOT data. The evaluation and potential applications should apply to Pacific island environments where small plot agriculture is widely dispersed in small irregular localised areas often within forests or adjacent to forest margins.

Although much of such intensive cropping is small scale and often at subsistence level yet in total the overall productivity is substantial and vital to the economy of the island communities. The better monitoring of such areas from SPOT data is a potentially useful tool.

RESUME

L'un des premiers objectifs du système SPOT est d'améliorer les possibilités de contrôle des ressources de petites zones agricoles depuis l'espace.

Ce papier présente une recherche sur l'utilisation de SPOT pour contrôler des activités horticoles de faible extension. Il explicite les relations spectrales et spatiales de cultures dispersées avec les classes adjacentes de couvert végétal et d'utilisation des sols ainsi que le rôle de l'échelle. Des exemples sont proposés à partir de données sur la Nouvelle-Zélande. L'évaluation réalisée et les applications potentielles peuvent être développées pour des environnements des îles du Pacifique où de petites zones agricoles sont largement dispersées dans de petites zones irrégulièrement localisées, souvent à l'intérieur de forêts ou adjacentes aux zones forestières.

Bien que la plupart de telles activités agricoles intensives soient réalisées à petite échelle, et souvent au niveau de la subsistance, la productivité globale est toutefois substantielle et vitale pour les économies insulaires. Un meilleur contrôle grâce à SPOT est un outil à fort potentiel.

INTRODUCTION

Four areas, two in North Island, New Zealand and two in Viti Levu, Fiji, are considered in this investigation. The New Zealand examples are the Tauranga-Te Puke area of intensive horticultural farming in the Bay of Plenty, and the Ormond viticultural area of the Waipaoa Valley in Eastland (fig.1). The Fiji examples are Navua and the Nausori Highlands, both on the western side of the predominantly forest covered island of Viti Levu (fig.2). Small fields of intensive village cropping in an alluvial valley flanked by forest at Navua are representative of localised areas of productive soils and more or less permanent cropping. The Nausori example is of a small village clearing within the forested uplands. A range of scattered subsistence cropping on slash and burn areas irregularly flank such settlements. Crop areas are small, diverse, often mixed and short term. As soil fertility becomes depleted new areas are cleared for cropping. After a period of time the whole small village may move to newer (temporarily more productive) forest areas.

All four areas are characterised by year round plant growth. The natural vegetation was complex stratified rain forest. Mild, moist, temperate, year-round growth supported temperate rain forest in New Zealand. Warm, moist, year-round growth supported tropical rain forest in Fiji. Such climatic conditions are favourable to a wide range of cultivated crops.

Although LANDSAT MSS data has been shown to be useful for mapping large area agriculture in tropical environments (Cochrane, 1986) it is not suitable for mapping the small area agriculture of Navua and Nausori. Nor was it found suitable for analysis of the land cover patterns of the New Zealand Te Puke and Ormond areas. Selected New Zealand SPOT subscenes were enlarged to a range of scales (1:100,000 - 1:15,000) for mapping and analysis of detail that had not been found possible from earlier analyses with LANDSAT-MSS data of these areas.

Spectral variations of the colour combined multispectral (XS) SPOT data of New Zealand, recorded as tonal variations, were analysed and the patterns mapped. Subsequently detailed reconnaissance of the mapped patterns were carried out in the field for the selected examples. Augmenting this initial visual survey digital analyses using both supervised and unsupervised classifications have begun but are not included in this report. This paper focuses upon the practical application of using enhanced photographic products from SPOT XS data for individuals or organisations with limited resources, and where access to complex sophisticated image processing may not be available.

Relatively small areas of intensive cropping that could not be identified from LANDSAT-MSS data can be mapped using the improved spatial resolution of 20 metres of SPOT XS data. Monotemporal selection of SPOT data optimising on crop phenology characteristics further improves the capabilities for mapping.

METHODS

Monotemporal SPOT XS data were selected for two different New Zealand scenes to test the capabilities of the satellite data for mapping of small intensive cropping, horticulture and viticulture.

SPOT scenes of late summer (18 March 1986) of Waipaoa and Gisborne areas (447/427, 447, 428) and a winter scene (5 August 1986) of the Te Puke area (443/426) were colour combined (XS1, 2, 3, blue, green, red), contrast enhanced by linear stretch and reproduced as images at 1:250 000 scale.

To test the optimising of selected temporal monitoring with SPOT it was hypothesised that late summer SPOT XS data would be valuable for differentiating between vines, pip and stone fruit orchards, citrus groves, maize and pasture crops. Similarly it was believed that winter SPOT data would be optimal for differentiating kiwifruit from citrus, maize (fallow) and pasture. These have been tested for the Ormond and Te Puke areas respectively. Because of the vigorous growth of all those different crops in spring and summer SPOT data for these periods would not be able to differentiate crops as all would have similar spectral values.

TE PUKE AREA

When first cleared from forest late last century the combination of the mild, moist climate and free draining soils of the broad interfluves of the eastern flanks of the Kaingaroa ignimbrite plateau (fig. 3) and terraces of Pleistocene silts proved excellent for high quality pastures. During this century intensive citrus horticultural development occurred (colour P14B). Transverse shelter belts of largely evergreen trees (Pinus and Cupressus) were established around boundaries of citrus orchards. Major shelterbelts were aligned west-east to protect the citrus orchards from cool southerly winds.

During the past two and a half decades initially a slow but increasingly rapid and dramatic transformation has occurred. Kiwifruit, a horticultural crop of perennial deciduous vines on trellised supports (colour fig. P14C), have replaced many of the evergreen citrus orchards. Additionally, much of the surrounding pasture areas on these well drained, north facing (sunny aspect) interfluves have also changed to kiwifruit orchards. Comparison of fig. 4, a section of a NZMS 260 Series topographic map showing 1977 land use patterns with the SPOT XS 1986 subscene, (colour fig. 14A), clearly shows the very recent expansion of kiwifruit into former pasture areas. This comparison also demonstrates the useful updating role that SPOT data can provide (Chen and Khan, 1988).

Kiwifruit is very sensitive to wind so additional subdivisional shelterbelts have transformed the former citrus areas into distinctive smaller cellular components. This same pattern is present in the newer areas developed from pasture. Initially a range of synthetic materials, such as pvc netting and slats on tall pole frames, were used before a range of quick growing deciduous shelterbelts especially willows (Salix) and poplars (Populus) replaced these. The dense foliage of deciduous species shelterbelt trees provide excellent protection for kiwifruit during the growing season (colour figs P14C and P14D). During winter when leaves have all fallen this allows maximum penetration of sun and ventilation which is beneficial for the orchard areas (colour fig. P14C). These quick growing deciduous shelterbelt species are carefully managed. They are closely spaced, trimmed laterally and topped to desired heights.

This physical patterning plus the marked seasonal change can be used to separately map citrus and kiwifruit areas if appropriate monotemporal SPOT data are selected. See colour figs. P14A, P14B and P14C. Citrus occupy larger blocks than kiwifruit, they are evergreen with a distinctive dark red year-round spectral tone on the simulated colour infrared (CIR) image (colour fig. P14B). Kiwifruit occur in smaller cellular units, they lose their leaves in winter so bare ground provides the major irradiance during this period (colour fig. P14C). During the growing season large mesic leaves of the dense kiwifruit foliage form a continuous canopy over the trellises completely masking the soil. Spectral tones are bright reddish on the simulated CIR imagery during spring and summer but greyish in winter. This winter contrast optimises classification between citrus and kiwifruit orchards.

Colour fig. P14A shows a winter (5 August, 1986) SPOT subscene of the Te Puke area. As noted earlier west-east aligned evergreen shelterbelts traverse much of the Te Puke horticultural area. Many of these show as thin dark west-east lines on the SPOT XS image (colour fig. P14A). These thin dark west-east lines of tall evergreen shelterbelts transverse to both the near-south orbit path and the sun viewing angle of SPOT show more readily than the north-south ones because the combination of height and shadow forms a distinctive single pixel value for the transverse shelterbelts. This shadow factor does not apply for most of the north-south aligned shelterbelts. Additionally many of the north-south shelterbelts are of deciduous species. The grey tones are the combined spectral response from the deciduous bare vines, the trellising and the bare soil beneath (colour fig. P14A).

Within the Te Puke area (fig.4 and colour fig. P14A) with this SPOT XS subscene winter data the cellular patterned grey tones are kiwifruit orchards, pinks represent permanent pasture, dark redbrowns the evergreen citrus foliage and cyan are bare ploughed areas which will be planted to maize in the spring. Spring and summer data would show the total area with universally high near IR reflectance (bright pinks and reds). Crop differentiation would be impossible as pastures, maize, deciduous shelterbelts, deciduous kiwifruit, evergreen citrus and evergreen avocado orchards would all be in full foliage and growth with similar spectral signatures. Even with digital analysis of DN values rather than visual comparison of colour tones separation of these various classes of land cover cannot be achieved with accuracy for spring and summer data (Jewell, 1988).

Colour fig. P14D, which is an October (spring) ground natural colour photograph of spring foliage of deciduous kiwifruit and shelterbelts, in an alluvial valley with pasture on the rolling hills beyond all vegetation is lush and green. Differentiation on the basis of SPOT XS data would be impossible. In contrast colour fig. P14C, although taken in early spring, still shows the bare soil and largely bare vines so that soil is the major contribution for spectral irradiance. It certainly is so during winter.

Thus for the Te Puke area differentiation of kiwifruit areas is optimised using winter spectral data.

ORMOND AREA

Within the Ormond area in the valley of the Waipaoa River (fig. 1 and colour fig. P14E) the alluvial river flats support crops of pasture, maize, vines and stone fruit orchards. Vines do not have shelterbelts. If SPOT XS winter imagery is used the only vegetation that could be identified would be pasture areas. For all other crop areas bare ground would provide the major spectral irradiance. Vines are deciduous and pruned back to minimal stumps and canes. They would not show as the ground is ploughed (fallow). Similarly stone fruit orchards are deciduous. Individual trees cannot be resolved thus the main spectral irradiance value is provided by the soil surface which is often ploughed i.e. in fallow. This ground surface of orchard and vine areas provides the spectral signature on winter imagery. If this ground is ploughed it is not able, therefore, to be differentiated from fallow arable areas awaiting spring planting to maize.

Whereas winter SPOT XS data is valuable for identification of crops in the Te Puke horticultural/agricultural area it is not useful for crop analysis and mapping of patterns in the Ormond area of the Waipaoa area. This example is representative of large areas in Eastland.

Some vignerons and orchardists plant a winter green crop cover between the rows for ploughing under in the late spring. Such areas of ground cover crops cannot be differentiated from permanent pasture areas on the basis of their spectral properties.

With both spring and summer spectral data there are again area wide similarities that provide a more or less universal high spectral signature from the foliages of all crops. SPOT XS data of spring and summer are not useful for crop differentiation for such areas with lush growth of all vegetation (Jewell, 1988).

Also it has been noted above that winter SPOT XS data is not useful for crop classification in this area as bare soil, dominating several crop categories (maize, orchards, vines), provides the major common spectral signature.

Late summer is an optimal time for analysis in the Ormond area (colour fig. P14E). All major crop types present can be identified and mapped. Field crops are either mature or harvested, and are shown on the image as tones of yellow, or perhaps in fallow (cyan). Pastures show as pink tones or bright reddish if irrigated, but vines show as dark brown-red tones and can thus be readily mapped. Orchards show as darkerbrown tones. When SPOT XS data is enlarged to 1:50000 scale and cadastral data overlaid (colour fig. P14E) the exact field boundaries show very detailed information of crop spectral characteristics between each field. Even variation within a specific crop in a single field (e.g. Lot 16) can be observed reflecting variations in physical habitat (e.g. soil moisture or soil fertility differences) or farm management or possible pathological factors (colour fig. P14E).

This report is of research in progress using photographic tones of enlarged SPOT XS data for mapping crop categories. Parallel digital analyses are under way but are not reported here. This additional research involves establishing exact seasonal multiband spectral signatures of characteristic crops and digitally classifying them. As a consequence mapping and monitoring future change can be achieved quickly, accurately and in a cost effective manner (Bruneau et al., 1988).

NAVUA

Small irregular localised areas such as the alluvial flats flanking the stream of the broadened valley at Navua (colour fig. P14F) support a range of crops such as cassava, taro, yam, kumala, with small groves of bananas and mango trees (colour fig. P14F). Areas of individual crops are sufficiently large to be resolved with SPOT XS data (Guerrerov, 1988). Multitemporal surveys provide the best method for mapping such areas. A time should be selected to show bare soil areas to fix the locations separately from the forest and tree crops, then a later image taken when the field crops are growing to separate these crops from flanking small banana or mango groves and perhaps patches of sugar cane. Spectral signatures of these are different from the flanking forest. In colour fig.P14F the crop-soil signature of the yam crop in the foreground flat would be different from the bare soil areas and large leaved taro and dense ground cover of kumala and cassava beyond.

Additionally the characteristic spectral responses from different crop canopies, crop-soil signatures of a new crop and of bare soil areas separate such areas from flanking forest. Although small such areas of an individual crop type are sufficiently large to be represented by several or numerous pixels each with a distinctive spectral signature. Two levels of mapping should be possible. The first is a general one to map the areas of intensive agriculture cropping with a range, albeit subtle, of spectral signatures of the various crops (Gastellu-Etchegorry et al., 1988 ; Guerrorov, 1988). With enhancement and comparison of multitemporal data a second level of mapping separating out some individual crops should be possible (Chen & Khan, 1988). Although some suitable SPOT images have been taken over Fiji these have not been viewed to verify these assumptions.

NAUSORI

Colour fig. P14G shows a different pattern of cropping from that present at Navua. Areas are smaller, cropping is frequently mixed usually without any large area devoted to a single crop. Mapping of such agriculture is a question of differentiating a mosaic pixel signature of mixed crop response from relatively larger adjacent areas of grass and flanking forest. Classification is possible of such mixed subsistence cropping as a single composite group separable from the more uniform spectral response of village dwellings, grass, and forest. Gastellu-Etchegorry et al., (1988) have demonstrated the role of SPOT data for mapping similar small scale agro-forest ecosystems in Java.

Whereas variations in crop phenology can facilitate mapping by multitemporal sampling for crop areas like Navua monotemporal data at a time when grass growth is minimal or partially stressed would provide an optimal situation for mapping the small mixed subsistence agriculture of small forest clearings such as that of the Nausori Highlands (colour fig. P14G).

SUMMARY

A diverse range from New Zealand and Fiji of small crop/horticultural examples with varying spectral/areal relationships have been analysed.

High spatial resolution of the SPOT XS data provides flexibility in mapping applications. Mapping can be at regional scales for broad cropping patterns or if required it can be used at very detailed local scales for intensive field by field analysis of crop characteristics.

SPOT data is practical for inventory applications and for mapping of dispersed small area agriculture from space. Both the 20 metre spatial resolution of SPOT XS HRV instrument and its 8-bit spectral sensitivity provide substantial improvements over LANDSAT MSS. SPOT data in the form of multiband photographic products at scales of 1:250 000 for agricultural mapping for regional studies and at scales from 1:100 000 - 1:50 000 for detailed land use mapping are practical economic tools for individuals or organisations where computer processing resources are limited or unavailable.

Critical selection of monotemporal data provides a powerful mapping tool for preparing inventories to give accurate estimations of crop acreages at regional levels Winter data is optimal for horticultural analyses in the Te Puke area. Late summer proved best for mapping the viticultural-horticultural agricultural patterns in the Waipaoa valley. 'Dry season' dates would be optimal for recognising the small scattered mixed subsistence agriculture of forest clearings such as Nausori.

Multitemporal data would be required for small area "permanent" cropping as at Navua (which although dispersed is representative of considerable total area) to optimise mapping crop variations.

For some detailed land use mapping of complex horticultural, agricultural, viticultural, pastoral areas multitemporal data may be required.

With integration of SPOT XS and PAN products even better results should be possible for inventory, mapping and monitoring small area cropping (Batista et al., 1988 ; Kalyango and Muller, 1988).

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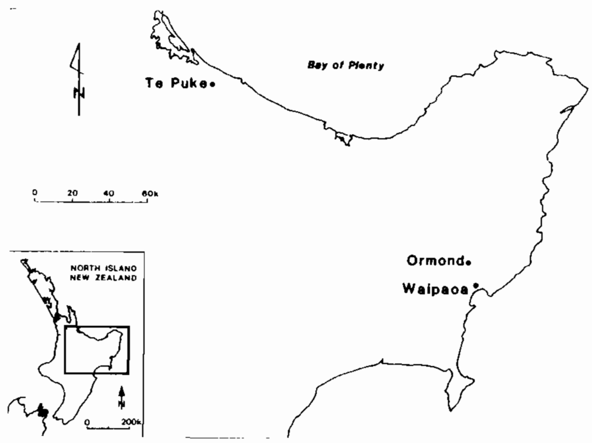

Figure 1 : Location map for SPOT XS subscenes, Te Puke and Ormond, North Island, New Zealand.

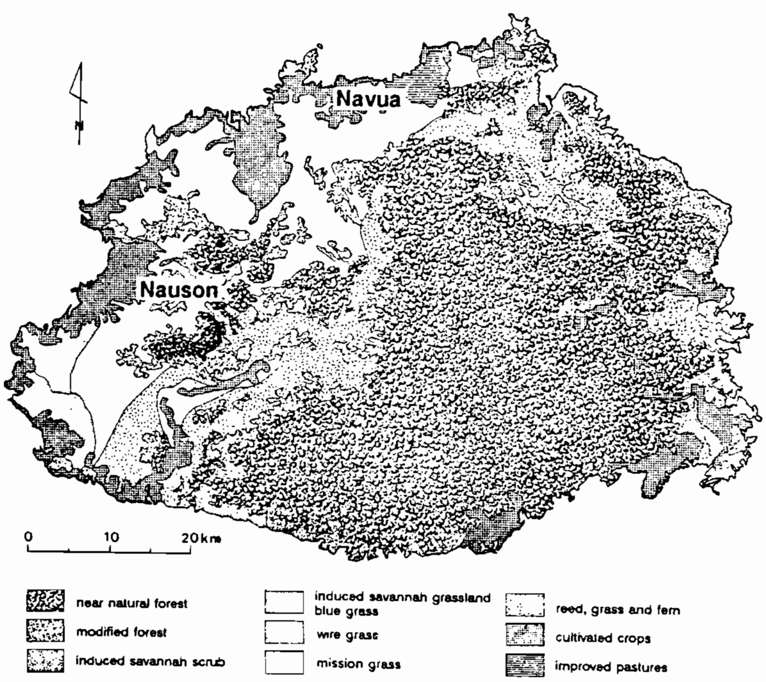

Figure 2 : Location map for Navua and Naurosi, Viti Levu, Fiji.

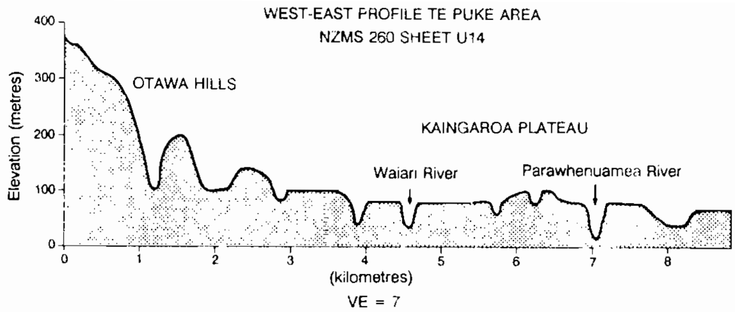

Figure 3 : West-east transverse profile across northern edge of Kaingaroa ignimbrite plateau, Te Puke. Location X-Y on Fig. 4.

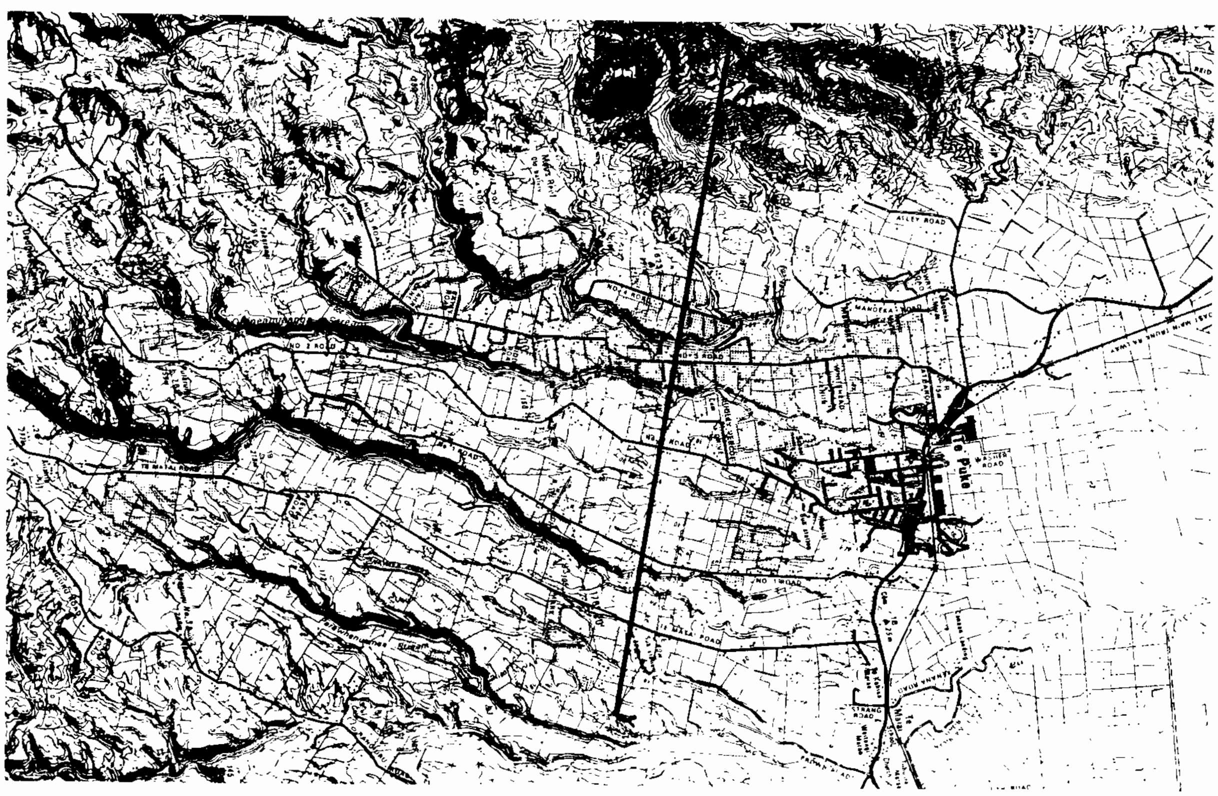

Figure 4 : Te Puke showing northern plain, urban area and horticultural-agricultural area of Kaingaroa plateau and flanking western volcanic hills from NZMS 260 1:50000 Series sheet U 14 topographic map reproduced in black and white at 1:100,000 scale. Orchard areas shown as a fine stipple. Compare with fig. 3 and colour fig. P14A.

P14A : Simulated CIR enhanced colour composite subscene of Te Puke horticultural area from SPOT XS (443/426) winter scene taken on 5 August, 1986 at scale 1:100,000 compare with figs. 3 and 4. Colour tones: grey - kiwifruit; pink - pasture ; cyan large areas - fallow; mixed cyan and pink patterns - urban Te Puke; dark red - citrus; dark brown-red - native forest ; thin dark lines - evergreen shelterbelts. Note the dissection of the relatively flat broad inter-fluves by the narrow, deeply incised, bush-covered gorges.
C CNES 86/dist SPOT IMAGE.

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P14B : Ground photograph of representative citrus orchard. Note the ever -green nature of the citrus and flanking shelterbelts, the large canopies of the trees and minimal area of earth between trees.

P14C : Ground photograph taken in October (early spring) of a representative kiwifruit area. Note the contrasting dark-toned evergreen, major shelterbelt and the lighter green new spring foliage of the secondary deciduous subdivisional shelterbelts. Some new spring foliage is present on the kiwifruit vines. These are bare during winter. Additionally the bare trellis frames, the bare ploughed soil and the bare deciduous shelter belt collectively contribute to give the grey tone of these areas on the SPOT XS winter subscene.

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P14D : Spring (October) scene of small kiwifruit orchard with its distinctive shelter-belts on a small alluvial flat nestled within rolling pasture covered hills of Pleistocene silts adjacent to the Kaingaroa Plateau. Spectral reflectances from the entire area would all be high in near IR and similar in the visible wavelengths thus giving a nearly uniform response on a SPOT XS scene. Differentiation of crop classes would be difficult on such a spring or summer image. By contrast a winter scene would clearly separate out the deciduous kiwifruit orchards (colour fig. P14C) from pasture.

P14 E : Simulated CIR enhanced SPOT XS colour composite subscene of Ormond, Waipaoa Valley, East-land at a scale of 1:50000. Cadas-tral data has been superimposed on this late summer (18 March 1986) SPOT subscene. Note particularly the ease with which crop categories can be mapped on the basis of their distinctive colour tones. See text for details. C CNES/dist SPOT IMAGE.

P14F : Small village permanent agriculture Navua, Fiji on fertile valley soils. Land cover classes present or include bare soil, partially grown yam, broad leaved taro in the foreground and middle distance and other crops occur beyond. Individual crop areas are large enough to be resolved from SPOT XS data.

P14G : A wide range of mixed subsistence agriculture crops growing together in the forest cleared margins adjacent to a small village settlement in Nausori, Fiji. Aggressive colonising grasses replace crops and forest species when soils become depleted from this form of shifting subsistence agriculture.

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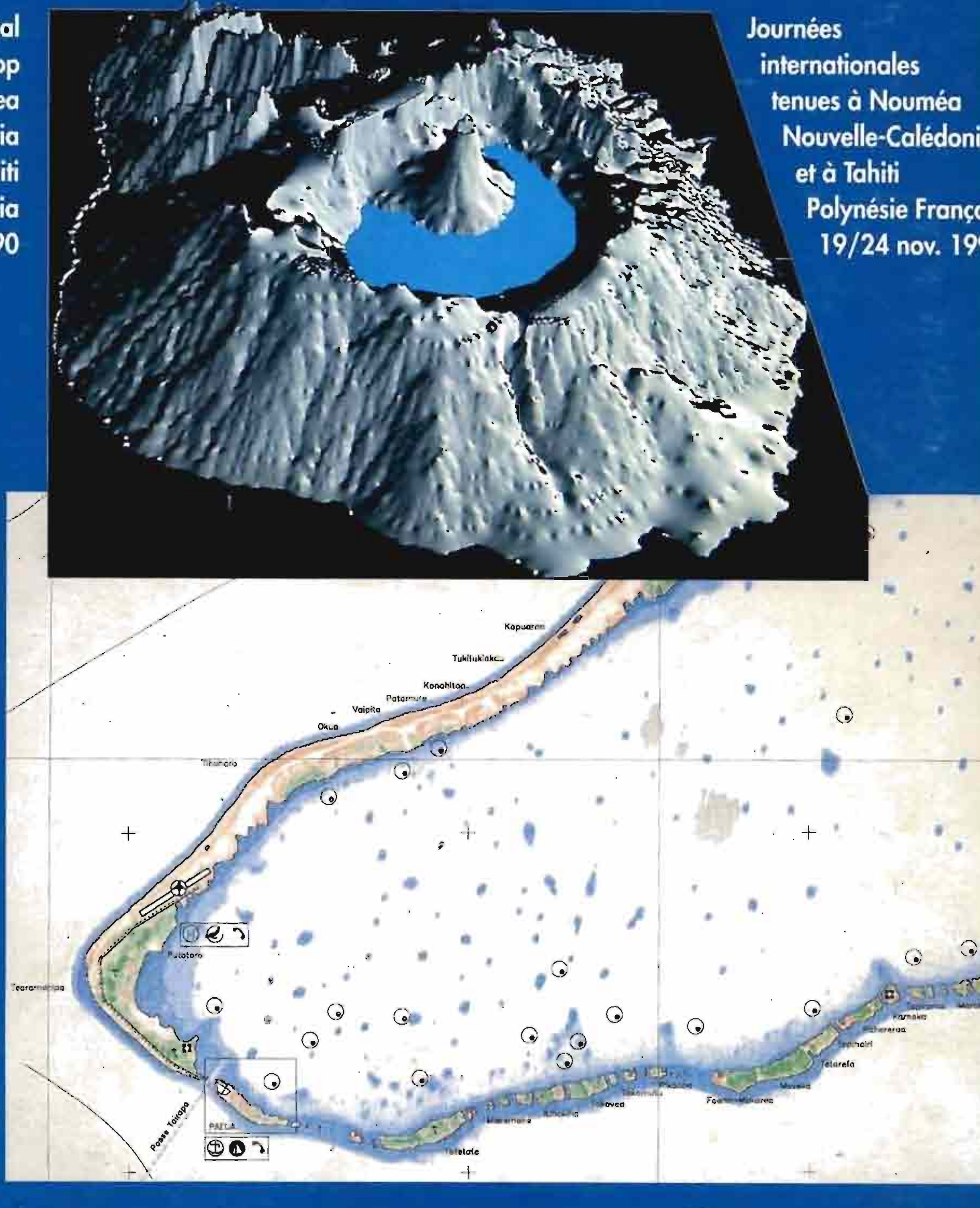

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