USE OF SPOT SATELLITE IMAGERY TO ASSESS SOIL EROSION CAUSED BY CYCLONE BOLA IN THE MAJOR FORESTS OF GISBORNE-EAST COAST, NEW ZEALAND.

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ABSTRACT

SPOT Satellite imagery was used to assess the effect of a single storm in terms of the increase in bareground by comparing 1986 SPOT XS and 1988 SPOT PAN imagery for the major forests of Mangatu, Tokomaru and Ruatoria of the Gisborne-East Coast, New Zealand. DRAGON software was used on a personal computer to enhance, register and classify eleven selected sub-images, each of which covered an area planted with *Pinus radiata* in one of four different age classes.

Classification results showed that younger age classes (less than eight years old) have less effect in preventing erosion than plantations more than eight years old. The older stands had considerable effect in controlling erosion in the forests of Mangatu, Tokomaru and Ruatoria.

INTRODUCTION

New Zealand deservedly has a word-wide reputation for the excellence of its pastures and for its high standard of grassland management. Highly developed pastures of the plains, and the easier hill slopes have a stocking capacity which is envied by most of other countries. These lowland soils are stable and, usually highly fertile, under the practice of intensive grassland and livestock management.

Unhappily there is another side of the coin: the great success of New Zealand's lowland pastoral farming should not be allowed to obscure a history of injudicious land use elsewhere. In the higher rainfall areas, the felling of native forests, necessary to make way for the development of pastures was extended unwisely on the many hundred thousand hectares of steep and unstable hill country. Not only millions cubic meters of fine timber were burnt and wasted, but the soils also could not maintain their stability in the absence of a forest cover, and as a result a massive and widespread erosion occured. The major area where erosion was severe and its effects so disastrous that rehabilitation had to be tackled as a national problem was in the Gisborne-East Coast.

The Soil Conservation and Rivers Control Council set up a special committee to report on remedial measures for controlling erosion, and one of the committee's recommendations was that the worst eroded areas should be afforested. Counter erosion afforestation started in the region in 1960. According to 1990 statistics, more than 81,908 hectares were planted with *Pinus radiata* which constitutes more than 90% of the total plantations.

During 7-9 March 1988, tropical Cyclone Bola devastated the North Island's East Coast region. A peak rainfall of 916 mm in three days was measured inland from Tolaga Bay; 600 mm was common and 400-500 mm widespread. The Bola storm affected most of the East Coast region. All the old slip scars reopened and new shallow slips developed.

The study looks at the effectiveness of young *Pinus radiata* plantations on reducing soil erosion in the East Coast and clarifies the use of the SPOT satellite imagery for assessing the effect of storm events such as Cyclone Bola on slopes planted with *Pinus radiata*.

MATERIAL AND METHODS

SPOT Satellite imagery (SPOT-XS-1986 and SPOT-PAN-1988) was provided by the DSIR Land Resources Division, Aokautere, New Zealand. DRAGON software was used to enhance, register and classify the imagery on a personal computer.

Image registration: SPOT satellite imagery was first registered to the New Zealand metric map grid. The term "registration" is accepted to mean the alignment process by which two images of the same region are positioned to be coincident with respect to each other (Bernstein, 1978; Moik, 1980; Swain and Davis 1978). This was done by using cultural and terrain features from topographical maps as ground control points (GCP's). These are often road intersections, field boundries, the edges of water bodies and airport runways (Bernstein, 1976; Benny, 1983). GCPs were selected on both the image and NZMS 260 series map (1:50,000).

Working with the coincident images, the cookicutter option within DRAGON was used to cut irregular-shaped areas comprising different compartments belonging to a particular age class in the SPOT-XS image. Masking technique was used to ensure exactly the same area from SPOT-PAN image. In this way areas of particular compartments having irregular shapes in both images were extracted.

As the SPOT-XS resolution was 20 meter and SPOT-PAN resolution was 10 meter, there was a need to bring these images to a single resolution. The software system allowed us to do this by assigning different values for the X and Y coordinate transforms in the registration process to bring them at par.

Image enhancement: Image enhancement procedures are applied to image data in order to display the data more effectively for subsequent visual interpretation (Lillesand and Kiefer, 1987). The range of possible image enhancement and display options available to the image analyst is virtually limitless. Choosing the appropriate enhancement for any particular application is an art and often a matter of personal preference. A linear contrast stretch ehancement technique was applied to the image under investigation. Patterns that were indistinguishable in the low contrast original were now readily apparent.

Using enhanced images eleven sites were selected for classification. The area and proportion of the forest represented by each of the study site is shown in Table 1.

Table 1. Study areas selected from the three forests, their area and its relation to the total forest size.

Study site	Area (ha)	% of forest size	Forest Name
A 1	144.5	1.3	Tokomaru
A 2	323.1	2.5	Mangatu
B 1	414.2	3.7	Tokomaru
B 2	263.0	2.3	Tokomaru
B 3	176.2	1.3	Ruatoria
C 1	123.2	0.9	Ruatoria
C 2	280.3	2.2	Mangatu
C 3	207.1	1.6	Mangatu
D 1	68.4	0.5	Ruatoria
D 2	86.6	0.6	Ruatoria
D 3	91.9	0.7	Mangatu

Four age classes: (A: 1-4 years; B: 5-8 years; C: 9-12 years and D: 13-16 years) of *Pinus radiata* were chosen using species distribution maps of Mangatu, Tokomaru and Ruatoria forests. Three sites in each age class were found except for age class 'A' in which only two sites were available.

Image classificiation: Image classification involves procedure applied to digital image data to categorize automatically all the pixels in an image into land cover classes. The categorized data can be presented in thematic maps of land cover or summary statistics of the area covered by each land cover type. There are three kinds of land cover classification which are usually used in the classification procedures, namely: Spectral Pattern Recognition, Spatial Pattern Recognition and Temporal Pattern Recognition. The choice of these Procedures mainly depends on the purpose of classification. In terms of spectrally oriented classification procedures, there are two types of classification that are commonly used. They are supervised and unsupervised classification. In the supervised classification the analyst defines useful information categories and then examines their spectral separability, whereas in the unsupervised classification, the analyst determines spectrally seperable classes and then defines their informational utility (Lilles and Kiefer, 1987).

In this study, a simple supervised classification was used to extract spectral signatures for each ground cover class. Two classes of interest i.e. vegetation and bareground were separated in each image by determining the range of intensity values for each class.

RESULTS AND DISCUSSION:

Figures 2 and 3 show both the original and classified images for a study site.

Ground truthing could not be carried because the study area was very vast, far away and inaccessible. However from visual comparisons between the original and classified image, the accuracy seems to be about 85% and many researchers report accuracies of 85 to 95% for their land cover maps.

Table 2. Classification results-Percentage of vegetation and bareground before and after Cyclone Bola for each study site.

Age-class Year	Imagery	Vegetatation	Bare-ground	Vegetation	Bare-ground	Vegetation	Bare-ground
A 1-4	Pre-Bola	94.2	5.8	95.2	4.8		
	Post-Bola	92.3	7.7	92.6	7.4		
	Difference		1.9		2.6		
B 5-8	Pre-Bola	94.7	5.3	94.7	5.3	96.4	3.6
	Post-Bola	92.5	7.5	92.2	7.8	90.5	9.5
	Difference		2.2		2.5		5.9
C 9-12	Pre-Bola	98.5	1.5	97.7	3.3	97.3	2.7
	Post-Bola	97.8	2.2	96.3	3.7	96.3	3.7
	Difference		0.7		0.4		1.0
D 13-16	Pre-Bola	98.5	1.5	96.1	3.9	93.2	6.8
	Post-Bola	98.3	1.7	95.3	4.7	92.1	7.9
	Difference		0.2		0.8		1.1

Table 2 shows the percentage of bareground and vegetation for each study site of different aged Pinus *radiata* before and after Cyclone Bola. Each study area is discussed below:

A (1-4 year old trees). Two study areas were selected in this age class. A1 is in Tokomaru Forest with an area of 144 hectares. New Zealand Land Resource Inventory work sheets were used to determine the slope and rock types of each particular site. This area has mainly agillite and mudstone and an average slope of 21° to 25° in the west and lower part, and 26° to 35° in upper north-east corner. The area had mainly three to four year old trees in 1988. Bareground before and after Cyclone Bola was 5.8% and 7.7% respectively.

Study area A2 lies in Mangatu Forest, has an area of 323 hectares and consists mainly of mudstones and sandstones. The slope varies between 21° and 35°. This area had a fairly good distribution of 1-4 year old trees. Bareground before and after Cyclone Bola was 4.8% and 7.4% respectively.

The increase in bareground was 1.9% in A1 and 2.6 in A2. Factors which may have contributed to the slightly higher increase in bareground in A2 are: 1) A2 was more than twice the area of A1. 2) A2 was planted with more one and two year old trees.

It was noted that classified images tends to discriminate slightly more bareground compared to a visual interpretation of the original images. This was mainly because the intensity levels of streams, roads and bareground were similar, therefore some roads and streams may have been included in the area classified as bareground in study area A2 and that is probably another reason it gives slightly higher percentage of bareground increase.

More sites were not examined in this class because adjoining areas having 1-4 year old trees were not available. The pattern of planting in these forests was such that each year only one or two compartments were planted. For this study adjacent compartments which represented the age class accurately were required and such areas were not available.

B (5-9 year old trees): Three study areas were selected in this age class. B1 and B2 in Tokomaru Forest and B3 in Ruatoria Forest. B1 had an area of 414 hectares. Rock types were argillites and mudstone. The average slope was 21° to 35°. Bareground before and after Bola was 5.3% and 7.5% respectively. This represented an increase in bareground after Bola of 2.2%.

Study area B2 was 263 hectares with an average slope greater than 35°. Bareground before and after Bola was 5.3% and 7.8% respectively, an increase of 2.5%. The variation in bareground increase between the two sites in Tokomaru Forest was quite small.

Study area B3 (176 hectares) was selected in Ruatoria Forest. The rock types were mudstone and argillite, and average slope was greater than 35°. Bareground before and after Bola was 3.6% and 9.5% respectively. The increase in bareground (5.9%) was much higher than similar aged stands in Tokomaru Forest. Ruatoria Forest is generally at a higher altitude and rainfall was much higher in higher altitudes and therefore much more erosion was likely to have occured in this area. Steepness and rock types probably also contributed to this higher erosion in B3.

C (9-12 year old trees): Three study areas were selected in this age class. C1 in Ruatoria Forest and C2, C3 in Mangatu Forest. C1 had an area of 123 hectare and an average slope of 16° to 25°. The most widespread rock type was argillite. Bareground before and after Cyclone Bola was 1.5% and 2.2% respectively.

Study area C2 was in Mangatu Forest with an area of 280 hectares. The average slope was 21° to 25° and bareground before and after Bola was

3.3% and 3.7% respectively. C3 also lies in Mangatu Forest, covering 207 hectares with an average slope of 21° to 25° and rock types mainly mudstone and argillite. Bareground before and after Bola was 2.7% and 3.7% respectively. The increase in bareground was 1.0%.

Study area C3 lies in between two big streams and stream bank erosion may have contributed significantly to the proportion of bareground recorded. Misclassification of streams and roads has affected the assessment of bareground in all the three sites in this class.

D(13-16 year old trees): Three study areas were selected in this age class as well. D1 and D2 in Ruatoria Forest and D3 in Mangatu Forest. D1 was 68 hectares with an average slope of 21° to 35°. Bareground before and after Bola was 1.5% and 1.7% respectively, an insignificant increase of 0.2%. This area represents the lowest increase in bareground among the study sites.

D2 had an area of 87 hectares and an average slope of 21° to 35°. Bareground before and after Bola was 3.9% and 4.7% respectively, an increase of 0.8%. D3 lies in Mangatu Forest. Its area was 92 hectares with an average slope of 21° to 35°. Bareground before and after Bola was 6.8% and 7.9% respectively, giving an increase of 1.1%.

CONCLUSION: Overall, age class A (1-4 year old trees). and age class B (5-8 year old trees) had almost the same rate of increase in bareground after Cyclone Bola. Age class C (9-12 year old trees) and age class D (13-16 year old trees) had almost the same rate of increase in bareground after Cyclone Bola. The increase in bareground in younger trees of *Pinus radiata* 1-8 year old was almost double that of the 9-16 year old trees.

In general, the variation in the results at each site are due to site conditions such as soil, rock, aspect, relief and slope, and these site conditions have considerable affect on the type and rate of soil erosion.

These results demonstrate that the erosion rate decreases as the forest matures. Particularly, erosion rate decreases considerably once the trees reach the age of 8 years.

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REFERENCES

Benny, A.H. 1983. Automatic location of ground control points in landsat imagency. International Journal of remote sensing 4: 235-42.

Bernstein, R.1976. Digital image processing of Earth Observation sensor data. IBM Journal of Research and Development, 20: 40-57.

Bernstein, R. 1978 (ed) Digital image processing for remote sensing. New York, IEEE Press.

Lillesand, T.M. and R.W. Kiefer, 1987. Remote sensing and image interpretation. 2nd Ed.John wiley and Sons. N. York. 21 P.

Moik, J.G. 1980. Digital processing of remotely sensed images, Washington D.C., NASA 77-126 pp.

Swain, P.H. and S.Davis 1978. Remote sensing. A quentitative approach. McGraw Hill Book Co. 396 pp.

Short, N.M. 1982. The landsat tutorial work book. Basics of Satellite remote sensing, Washington D.C. NASA scientific and Technical. Information Branch p 74-75.