MODELING FOREST STAND PARAMETERS FROM LANDSAT THEMATIC MAPPER (TM) DATA

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ABSTRACT

Landsat Thematic Mapper (Landsat TM) satellite data were evaluated for the estimation of forest inventory variables for a study area near Fort Simpson, NWT. Field data was collected from 106 plots to develop empirical models that defined the relationships between stand variables and Landsat TM data. There was a trend of increasing height, age, and crown closure with decreasing reflectance that was attributed, in part, to the proportions of shadow and reflectance from tree crowns and the understory. Models developed to predict stand variables from remote sensing data were stronger for primary successional species, including jack pine and trembling aspen, because the changes in their structure and composition were consistent at each successional stage, over the range of stands sampled. Models were frequently weaker for white spruce, a secondary successional species, and mixed-wood stands since there was greater variability in the structure of these stands due to the different successional pathways that govern their establishment and dynamics.

1.0 INTRODUCTION

Sustainable development and management of the Canadian North's natural resources are among the primary responsibilities of the Department of Renewable Resources, Wildlife and Economic Development (RWED), Government of the Northwest Territories (GNWT) (Forest Development Services 1998). To best manage the forest landscape and ensure that management practices are sustainable, RWED requires detailed forestry information on the location, structure, composition and spatial distribution of forests that span large, remote, regions of the NWT. Information about stand species composition, height, age, crown closure and volume are required to best formulate decisions that would help contribute to the sustainable development and management of the forest resources of the NWT. While this information is typically collected through forest inventories, the amount of land surveyed in the NWT is limited due to accessibility and the high costs associated with field sampling. For this reason, few forest inventory maps have been produced from detailed air photo interpretation and field site visits, as sampling procedures to acquire this information are logistically difficult and economically impractical.

There is a need to develop alternative methods for extracting broad forest inventory information in the NWT at relatively low financial costs. The integration of satellite remote sensing with NWT inventory surveys is one approach that could help managers meet these information demands. Past studies have demonstrated the utility of remote sensing data for providing broad estimates of stand variables, including stand height (De Wulf *et al.* 1990; Cohen and Spies 1992), age (Fiorella and Ripple 1993; Cohen *et al.* 1995; Jakubauskas 1996), crown closure (Butera 1986; Deuling *et al.* 2000), and volume (Ripple *et al.* 1991; Gemmell 1995; Trotter *et al.* 1997). While these studies have indicated promise for deriving estimates of inventory variables in a variety of ecosystems, the empirical nature of these studies made it difficult to determine how well these inventory variables could be estimated in the northern boreal region of the NWT. The objective of this research was to determine the extent that broad forest stand variables, that include height (m), age (years), and crown closure (%), can be estimated from a late-summer Landsat TM image in a northern boreal ecoregion.

2.0 STUDY AREA AND DATA COLLECTION

2.1 STUDY AREA

The study area for this research is located within the Boreal forest zone, a broad northern circumpolar belt that is found in many regions along the northern hemisphere. The specific region of interest for this study is centered near the village of Fort Simpson, which is located within the southwestern portion of the NWT. This region is situated within the Upper Mackenzie (B.23a) forested region characterized by Rowe (1972) and the Ecological Stratification Working

Group (1995). This site is dominated by typical North Boreal species, including white spruce (*Picea glauca* (Moench) Voss), balsam poplar (*Populus balsamifera* L.), trembling aspen *(Populus tremuloides* Michx.), jack pine (*Pinus banksiana* Lamb.), black spruce (*Picea mariana* (Mill) B.B.P.), tamarack (*Larix larcina* (Du Roi) K. Kock) and white birch (*Betula papyrifera* March) (Day 1968; Rowe 1972).

2.2 FIELD DATA COLLECTION

Field data was collected during July and August 1999 at 85 field plots located in pure jack pine (25), white spruce (32), aspen (28) and mixed-wood (21) stands. Variable radius plot surveys, using a basal area factor (BAF) of 2, were used to survey each stem in the plot for diameter at breast height (dbh) and height. Estimates of crown closure, the percentage of land area covered by the vertical projection of tree crowns, were undertaken with the aid of a spherical densiometer. Percent species composition was determined by calculating the percentage that each species type contributed to the overall species composition in the plot, based on the total basal area for each tree species. Finally, age was determined by counting tree cores obtained from the leading tree species within each plot. Geographic locations were determined for each study plot by transferring air photo pin-prick locations to forest inventory maps, these points were digitized and transferred over to the georeferenced image data.

2.3 LANDSAT-5 THEMATIC MAPPER (TM) DATA

Landsat-5 Thematic Mapper (TM) data were acquired during August, 1993, over the Fort Simpson region (track/frame 51/18). This image was chosen for analysis, even though its vintage was old and the sun-angle was extremely low, which could introduce variability into the stand variable models, since it is the most recent cloud and smoke free image available for the region.

3.0 METHODS

3.1 IMAGE PRE-PROCESSING

The Landsat TM image was atmospherically corrected, to reduce the effects of atmospheric scattering, and converted to reflectance digital numbers (DN's) using the PCIWORKS atmospheric correction package. The correction process worked well in most regions of the imagery, removing much of the image haze, however, a thicker layer of haze remained in some regions, and could not be completely corrected for. The image was geometrically corrected using PCI GCPWORKS from 60 ground control points (GCP's) that were identified from road, seismic line, hydrography and forest polygon data contained in a GIS database. Difficulties were encountered when rectifying the scene due to the lack of identifiable controls points that could be identified throughout the study area and the vintage of basemaps available for the NWT, which were created in the early 1970's. A first order polynomial transformation model was used to assign geographic and UTM coordinates to the Landsat data and nearest neighbour (NN) resampling was applied for assigning DN values to the rectified imagery. The error resulting from this correction process was less than 1 pixel (30 m) in size, despite the overall difficulties in locating accurate control points.

3.2 VEGETATION INDICES AND TRANSFORMATIONS

Ancillary digital information is often used to increase the amount and variety of data that is supplied to classifiers or regression models to increase the overall level of precision that may be achieved (Hutchinson 1982; Stehman 1996). Mathematical and statistical operations performed on the original spectral data are often used to derive new ancillary variables, such as vegetation indices and band transformations. In this study three vegetation indices and Landsat TM Tasseled Cap Transformations were used, in addition to spectral reflectance data, to provide estimates of stand variables.

The first vegetation index derived was the Normalized Difference Vegetation Index (NDVI) (Rouse *et al.* 1974). The next two vegetation indices applied in this research were infrared indices. These were utilized since various studies have demonstrated that infrared bands contain a larger range of spectral information than visible bands (De Wulf *et al.* 1990; Franklin and McDermid 1993). Included in these infrared ratios were the Structural Index (SI), which is the ratio of TM bands 4 and 5 (4/5) (Fiorella and Ripple 1993), and the far infrared ratio, using TM bands 4 and 7 (4/7).

The Landsat TM Tasseled Cap Transformation was implemented to generate brightness, wetness, and greenness components, given that past work has reported relationships between these components and various forest mensurational variables (Cohen and Spies 1992; Cohen *et al.* 1995; Deuling *et al.* 2000). These transformations are used to transform a 6 vector space into 3 new channels of data (Crist and Cicone 1984). These transformations include: brightness (BR), which is a summation of the total scene brightness from all channels of data; greenness (GR), which is the contrast between the near-infrared and the three visible bands; and, wetness (WET), which is the degree of contrast between the mid-infrared (water absorbing bands) and other four bands (Crist and Cicone 1984; Crist *et al.* 1986).

3.3 DETERMINING RELATIONSHIPS BETWEEN STAND AND IMAGE VARIABLES

Prior to model development it was important to explore the field and image data, to better understand how stand variables were related to image reflectance and transformed values. Pearson's product moment correlation coefficients were calculated separately for each of the four species groups, to determine the relationships between stand variables and image extracted reflectance and transformed data. All correlation values that were significant at the 95% confidence interval ($p < 0.05$) were flagged with an asterisk (*).

3.4 MODEL DEVELOPMENT

Stand variable estimates were modeled individually for each of the four species groups, as a function of image reflectance, indices and transformation DN values. A multiple regression approach was applied using the backwards-variable selection procedure to determine which image variable should be input into the model. All significantly correlated variables, at the 95% confidence interval, were initially input to the regression model. The backwards-variable selection procedure was used to sequentially remove variables that did not meet selection criteria, where the variable that demonstrated the smallest partial correlation with the dependent variable was considered first for removal. The next variable remaining in the equation with the smallest partial correlation was considered next. This procedure continued until there were no variables left in the equation that satisfied removal criteria.

Models of stand variables were compared by calculating the adjusted R-square and root mean square error (RMSE) values for each model equation. Overall model significance and residual plots were also used in assessing the strength and performance of each regression model.

4.0 RESULTS AND DISCUSSION

4.1 PREDICTING STAND HEIGHT

Stand height was negatively correlated with image reflectance and transformed values, which is a recurring trend observed in most recent studies (De Wulf *et al.* 1990; Cohen and Spies 1992; Franklin and McDermid 1993; Gemmell 1995). Band reflectance values consistently decreased as stand height increased (Table 1). For example, the strongest correlation with spectral bands included TM band 4 (near-infrared) with jack pine and white spruce height (R values of –0.62 and 0.51, and p values of 0.001 and 0.003, respectively) and TM band 5 with aspen and mixed-wood height (R = -0.65 and –0.63, and p = 0.0001 and 0.002, respectively). These infrared bands were most strongly t correlated with height, since their range of values in the database were the largest. The range of band values varied from 50 to 75 in TM band 4, which has been identified as a key factor for permitting the development of stand variable models (De Wulf *et al.* 1990; Franklin and McDermid 1993)

The negative relationship obtained was considered plausible because taller trees cast larger shadows that can create a decrease in the overall spectral response value detected by the satellite sensor. Furthermore, since stems/ha exhibited a negative relationship with stand height for all species (correlation values between height and stems/ha ranged from -0.62 to –0.88, p values below 0.0001), a decrease in stems/ha would have created more gaps in the canopy while stand height was increasing. These additional gaps would expose more shadows to the satellite sensor overhead, thereby further increasing the effect on the detected reflectance values.

The strongest backwards regression models that predicted height were developed for the two primary successional species (pine and aspen), which yielded the strongest adjusted r-square values (0.63 and 0.53, respectively p= 0.0001) (Table 2). The relationships worked best for primary successional species since their stands follow a consistent pattern of growth . Therefore, consistent changes in stand structure would occur with increased height, such as stem density and changes in crown closure . This homogenous stand development pattern would permit strong relationships to be formed between height and image values.

White spruce and mixed-species stands had much lower model strengths (adjusted r-square of 0.43 and 0.31, and p values of 0.001 and 0.005, respectively) (Table 2). Relationships for white spruce were weak, since spruce is a secondary successional species, and therefore the recruitment history and structural development of the species varies by site. Most often spruce is recruited beneath trembling aspen stands, however, spruce can also establish beneath pine stands or in open clearings. For this reason, the height structure and stem density of spruce stands could be variable across all sites, depending upon the successional pathway taken by the species. This would create a more heterogeneous stand structure, and thereby create a more variable relationship to be formed between height, stem density and crown closure at each height class. This could have introduced variability in stand reflectance values, thus weakening the model results.

The relationship between mixed-wood stand height and image reflectance/transformed values were weak, and was attributed to the large variability in height structures and species composition found in mixed-wood stands. The spectral signatures obtained from each plot were variable as a result of the varying stand heights Variation in height results in different shadow patterns, and species compositions found within individual height classes, which would have introduced the error and uncertainty that existed in mixed-wood height models.

4.2 PREDICTING STAND AGE

The observed direction and strength of relationship between stand age and image reflectance/transformed values were very similar to those observed with stand height (Table 3). This was expected since strong relationships were generally observed between stand height and the age of the stand.

Jack pine and aspen stand height was strongly associated with age ($R \approx 0.8$, p values near 0.0001), while white spruce had a weaker relationship ($R = 0.59$, $p = 0.001$). Since pine and aspen age is strongly related to height, the correlation between age and TM band reflectance was similar to those obtained with height (Table 3). This was an expected result, since past studies that examined the relationship between Landsat data and both height and age demonstrated very similar results between each of the derived correlation coefficients and model strengths (DeWulf *et al.* 1990; Cohen and Spies 1992; Gemmell 1995). The correlation coefficients for spruce age and reflectance were weaker, which could have been expected with the weaker relationship between spruce age and height.

Similar to stand height, the relationship between age and TM band values were highest for pine and aspen stands (Table 3), and was thought to occur because these were primary successional species. Therefore, stand structural development would follow similar trends within each successional stage for these stands. This pattern was interpreted to be the key factor that permitted the development of moderately strong regression models to predict pine and aspen age, with adjusted r-square values of 0.62 and 0.59 (p values of 0.0001), and standard error of estimates near 23 years (Table 2).

A weaker relationship was observed between white spruce age, and image reflectance and transformed DN values (Table 3). This may also be attributed to the different ecological factors that influence the growth and distribution of white spruce stands. Growth patterns and trends associated with white spruce succession (such as patterns in height, crown closure and stems density) were not as definitive as those exhibited by primary successional species. The variability in stand structural development introduced variability in stand reflectance values for individual age groups, thereby yielding a weak regression model, when compared to the pine and aspen models (Table 2), with an adjusted r-square value of 0.36 ($p = 0.001$) and a high standard error of estimate around 30 years.

The relationship between mixed-wood stands and image reflectance/transformed values was weak and attributed to the large variability in stand species composition and structures found throughout the study plots. The spectral signatures obtained from each plot would be variable, due to the different species compositions and height classes associated with each age class, contributing differing spectral values due to species reflectance and shadows. Further, the variable relationships between spruce, aspen and pine that are contained in the mixed-wood stands would create further confusion in the relationships observed. For this reason the mixed-wood multiple regression model had a weak adjusted r-square value of 0.21 ($p = 0.028$) and high standard error of estimate (around 41 years) (Table 2).

4.3 PREDICTING CROWN CLOSURE

Relationships between crown closure and image reflectance and transformed values varied significantly from those observed with stand height and age. No relationship was observed between crown closure and either image reflectance or transformed values for both the aspen or mixed-species stands (Table 4). Jack pine was positively related to crown closure and both Landsat TM spectral reflectance and transformed data, while white spruce demonstrated a negative relationship with spectral data and positive relationships with transformation data (Table 4).

The lack of relationship between aspen crown closure and reflectance, and transformed values could possibly be due to the poor relationship between crown closure and stand variables (height and age). Since no relationship existed it was interpreted that crown closure would vary for similar height and age classes. This may occur since taller and more mature stands would have larger crowns, with deep gaps throughout the crown layer, creating a heterogeneous canopy with patches of shadows. A young stand, with a similar crown closure, would have a more homogenous canopy structure with fewer crown gaps. The younger stand would have higher reflectance values than the mature stand, due to the smaller amount of canopy gaps. This tree crown arrangement pattern was thought to be one key factor that prohibited a relationship to be formed between Landsat data and crown closure (Table 4), thereby preventing a multiple regression model to be built for aspen crown closure (Table 2).

The relationship between mixed-wood spectral response and crown closure was statistically insignificant, and thus the development of a multiple regression model was not possible . This could be attributed to the variability in species type that makes up mixed-wood stands. As Gemmell (1995), Deuling *et al.* (2000), and others have found, mixed-wood reflectance values are influenced by species differences rather than pure differences due to crown closure.

The relationship between reflectance and jack pine crown closure was expressed as a positive association, whereby reflectance values decreased with a decrease in crown closure (Table 4). This relationship was result of the strong, inverse relationship that pine crown closure has with stand height (R=-0.73, p=0.0001). Since height has already been shown to have a strong, negative relationship with image reflectance and transformed values, the inverse relationship could be expected when correlating crown closure, thereby creating the positive association. Therefore, similar to height and age, the structural changes of pine stands that occur concurrent with changes in crown closure permitted a moderately strong regression model to be built to predict pine crown closure (adjusted r-square = 0.64, p = 0.0001 (Table 2).

White spruce crown closure is not associated with any stand factors, possibly because of the varying recruitment forms and successional pathways taken by the species. Therefore, the crown closure of spruce stands did not follow a consistent trend with height and age changes. Therefore, the moderately strong relationships between crown closure and reflectance values (Table 4) could be related to the biological factors associated with spruce stands in the NWT. In the NWT, white spruce is often found on moist, mesic sites. For this reason it may be interpreted that a full, dense, closed spruce canopy may hold more water when compared to a similar density stand of jack pine, due to the increased density of needles found on spruce trees. Therefore, if the leaf area increased, due to increased canopy closure, the absorption of middle infrared (TM 5) and far infrared (TM 7) energy by the water and cellular structure of these leaves would increase, which was demonstrated by the negative relationships for TM bands 5 and 7 (R values of –0.55 and –0.45, and p values of 0.001 and 0.01, respectively) (Table 4). As crown closure increased, the leaf area increased, the density of water holding needles increased, reducing the amount of energy that was reflected by the canopy. This argument is further supported by the strong relationship with crown closure and wetness values (R = 0.71, p = 0.0001) (Table 4), where wetness values increased as the canopy closure increased. Since moderately strong relationships existed between spruce crown closure and Landsat data a multiple regression model with an adjusted r-square value of 0.48 (p = 0.0001) and standard error of estimate of 7.5% could be created (Table 2)

5.0 CONCLUSIONS AND RECOMMENDATIONS

This research has been effective for identifying trends in the relationships between stand variables and Landsat TM data for dominant North American Boreal forest stands, including pure jack pine, white spruce, trembling aspen and mixed-woods, found in the southwestern Northwest Territories. Most often the general trend of increasing height, age, and crown closure with decreasing reflectance was identified in this study, which is consistent with trends that have been identified in other studies with similar research objectives.

It was identified that the strength of the models derived to predict stand variables differed, largely, according to the species type and successional pathways followed by these species, which lead to differing structural developments within each species stand. Models were generally strongest for primary successional species, including pine and aspen; whereby the relationship was interpreted as one that is determined by consistent successional changes in stand structure and composition. Secondary species, such as spruce, and mixed-wood stands provided weaker model strengths from Landsat TM data, which was thought to be attributed to the inconsistent trends in stem growth and stand structural changes.

The strongest overall models were for height and age, since both variables are related to stand structure, which can be modeled depending upon the amount of shadows cast by the canopy, and the amount of gaps that open as the stand matures. Crown closure models were not always dependent upon stand structure; since spruce crown closure was more related to stand biological factors, such as canopy water absorption ability. Pine crown closure was inversely related to height, while aspen and mixed-wood crown closures were unrelated to image data.

Future work could involve refining the research methodology to consider discrete classes of forest variables, rather than continuous data, using a discriminant analysis approach. This approach has the advantage of reducing the variability that must be explained among the variables; however, a disadvantage is that the level of detail would be reduced to two, three or four discrete stand variables. Additional work could be undertaken to build stand volume models, and may involve applying an alternate modeling approach that utilizes the predicted height, age and crown closure data as independent variables in a model to estimate volume through a system of equations. Solving variables simultaneously in a system of equations has been developed and implemented by those in econometrics, and has the advantage of distributing the error terms that may improve the ability to estimate volume (Border 1989).

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Table 1. Correlation coefficients between stand height and both image reflectance and transformed values for all species.

	Jack Pine		*White Spruce*		*Aspen*		*Mixed-wood*	
	R	Sig.	R	Sig.	R	Sig.	R	Sig.
TM1	0.12	0.575	-0.21	0.260	0.27	0.167	-0.24	0.291
TM2	-0.45*	0.024	-0.35*	0.049	0.04	0.838	-0.34	0.131
TM3	-0.22	0.297	-0.46*	0.008	0.21	0.284	-0.29	0.202
TM4	-0.62*	0.001	-0.51*	0.003	-0.57*	0.002	-0.58*	0.006
TM5	-0.20	0.326	-0.22	0.218	-0.65*	0.000	-0.63*	0.002
TM7	-0.17	0.425	-0.23	0.215	-0.17	0.378	-0.34	0.127
NDVI	-0.48*	0.014	0.00	0.986	-0.49*	0.009	-0.30	0.180
TM 4/5	-0.72*	0.000	-0.48*	0.005	-0.18	0.368	-0.17	0.469
TM 4/7	-0.48*	0.014	-0.39*	0.026	-0.29	0.128	-0.30	0.184
BR	-0.51*	0.009	-0.46*	0.008	-0.61*	0.001	-0.58*	0.006
GR	-0.65*	0.000	-0.39*	0.026	-0.57*	0.001	-0.58*	0.005
WET	-0.41*	0.044	-0.08	0.677	0.09	0.633	0.28	0.227

*** Statistically significant at p=0.05**

Table 2. Backwards multiple regression results for estimating stand variables from image data.

Species	*Stand Variable*	*R*	R^2	*Adjusted* R^2	*Std. Error*	*F*	*Sig.*
Jack Pine	Height (m)	0.85	0.72	0.63*	2.06 (m)	7.87	0.000
	Age (yr)	0.83	0.68	0.62 *	22.77 (yrs)	10.86	0.000
	Crown Closure (%)	0.83	0.69	0.64 *	4.83 (%)	15.26	0.000
	Volume (m^3/ha)	0.46	0.22	0.18*	39.22 (m^3/ha)	6.32	0.019
White Spruce	Height (m)	0.71	0.50	0.43*	3.30 (m)	6.78	0.001
	Age (yr)	0.63	0.40	0.36*	30.4 (yrs)	9.05	0.001
	Crown Closure (%)	0.71	0.50	0.48*	7.46 (%)	30.17	0.000
	Volume (m^3/ha)	0.75	0.56	0.47*	47.43 (m^3/ha)	6.54	0.000
Trembling Aspen	Height (m)	0.79	0.62	0.53*	3.47 (m)	7.21	0.000
	Age (yr)	0.81	0.65	0.59*	22.49 (%)	10.87	0.000
	Crown Closure (%)	-	-	-	-	-	-
	Volume (m^3/ha)	-	-	-	-	-	-
Mixed-wood	Height (m)	0.58	0.34	0.31*	4.04 (m)	9.87	0.005
	Age (yr)	0.50	0.25	0.21*	40.82 (yrs)	5.81	0.028
	Crown Closure (%)	-	-	-	-	-	-
	Volume (m^3/ha)	0.50	0.25	0.21*	63.93 (m^3/ha)	6.20	0.022

*** Statistically significant at p=0.05**

Table 3. Correlation coefficients between stand age and both image reflectance and transformed values for all species.

	Jack Pine		*White Spruce*		*Aspen*		*Mixed-wood*	
	R	Sig.	R	Sig.	R	Sig.	R	Sig.
TM1	0.06	0.759	0.14	0.465	0.34	0.074	-0.01	0.969
TM2	-0.52*	0.007	0.00	0.994	0.18	0.349	-0.16	0.522
TM3	-0.16	0.452	0.12	0.516	0.42*	0.027	-0.03	0.908
TM4	-0.49*	0.013	-0.35	0.054	-0.68*	0.000	-0.42	0.072
TM5	0.03	0.869	0.08	0.662	-0.60*	0.001	-0.43	0.067
TM7	0.08	0.705	0.00	0.999	-0.24	0.214	-0.08	0.729
NDVI	-0.41*	0.040	-0.42*	0.021	-0.68*	0.000	-0.41	0.082
TM 4/5	-0.71*	0.000	-0.56*	0.001	-0.39*	0.042	-0.15	0.548
TM 4/7	-0.57*	0.003	-0.43*	0.017	-0.34	0.075	-0.49*	0.032
BR	-0.34	0.093	-0.13	0.484	-0.64*	0.000	-0.37	0.119
GR	-0.50*	0.012	-0.46*	0.010	-0.69*	0.000	-0.50*	0.028
WET	-0.61*	0.001	-0.41*	0.026	-0.11	0.582	0.10	0.687

*** Statistically significant at p=0.05**

Table 4. Correlation coefficients between percent crown closure and both image reflectance and transformed values for all species.

	Jack Pine		*White Spruce*		*Aspen*		*Mixed-wood*	
	R	Sig.	R	Sig.	R	Sig.	R	Sig.
TM1	0.08	0.707	-0.23	0.215	-0.07	0.710	0.19	0.421
TM2	0.50*	0.011	-0.20	0.263	-0.13	0.515	0.18	0.431
TM3	0.25	0.223	-0.26	0.144	0.11	0.579	0.28	0.215
TM4	0.76*	0.000	-0.04	0.824	0.08	0.692	0.31	0.175
TM5	0.43*	0.030	-0.55*	0.001	-0.06	0.760	0.18	0.426
TM7	0.41*	0.040	-0.45*	0.010	-0.07	0.715	0.24	0.291
NDVI	0.60*	0.002	0.15	0.425	-0.04	0.859	0.09	0.707
TM 4/5	0.73*	0.000	0.43*	0.014	0.19	0.323	0.34	0.134
TM 4/7	0.44*	0.028	0.39*	0.029	0.19	0.325	0.13	0.566
BR	0.69*	0.000	-0.29	0.113	0.03	0.863	0.29	0.199
GR	0.75*	0.000	0.08	0.676	0.07	0.740	0.28	0.218
WET	0.26	0.204	0.71*	0.000	0.16	0.411	0.03	0.892

***Statistically significant at p=0.05**

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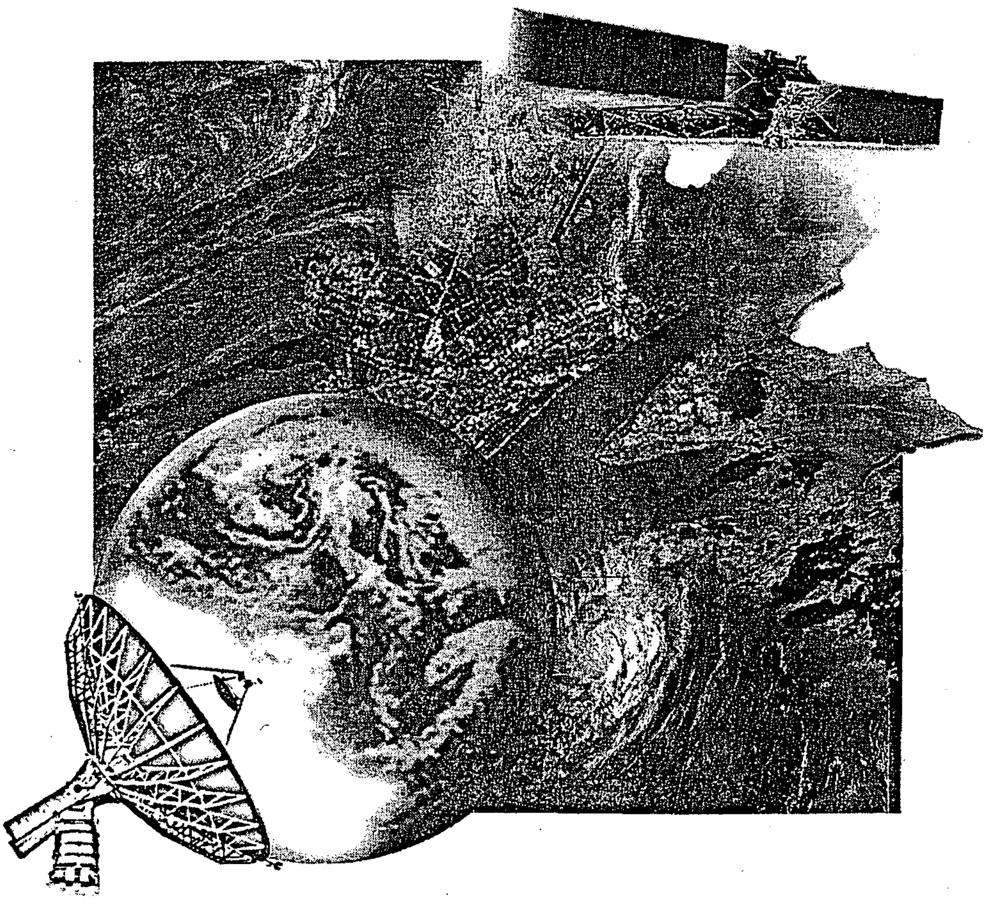

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