THE UNIVERSITY OF MANITOBA

TESTING PREDICTIONS OF HABITAT SUITABILITY FOR WHITE-TAILED DEER DERIVED FROM LANDSAT MSS IMAGERY

BY

WILLIAM RICHARD DARBY

A DISSERTATION SUBMITTED TO
THE FACULTY OF GRADUATE STUDIES
IN PARTIAL FULFILLMENT OF THE REQUIREMENTS
FOR THE DEGREE OF
DOCTOR OF PHILOSOPHY

MAY 1990

ISBN 0-315-71852-8

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ABSTRACT

Objectives of this study were to: (1) make predictions of white-tailed deer habitat suitability from Landsat MSS thematic map data, and; (2) test the hypothesis that such predictions are significantly ($P<0.05$) correlated with independent measures of habitat mosaic suitability, deer forage, cover and site characteristics.

A multi-date thematic map of deer habitat (average unbiased accuracy=77.0%, $P<0.05$) was produced by supervised classification for 3,500 sq.km of northwestern Ontario. Predicted ranks of 1 (optimal) to 5 (unsatisfactory) were generated for sq.km cells for summer, winter and year-round periods by comparing theme proportions and edge index to optimal standards derived from the scientific literature.

Three tests were performed on predicted ranks (1.00 to 5.00, n=66). Test 1 showed significant correlation between predicted and true year-round ranks of the habitat mosaic ($P=0.0001$, $R=0.785$). Test 2 showed significant canonical correlation of predicted year-round ranks with summary food, cover and site data ($P=0.0001$, $CC=0.784$), even though maximum attainable correlation was <1 because some variables had peak benefit for deer with values between possible extremes. Test 3 showed no significant correlation between predicted winter ranks and over-winter deer density ($P=0.3019$, $R=-0.098$, n=112), even after sq.km cells with

black spruce and larch-dominated forest stands were removed from the sample (P=0.1492, R=-0.165, n=78). However, deer concentrated in winter in portions of the good to optimal habitat, apparently as an anti-predator and energy conservation strategy.

The results required acceptance of the hypothesis. This habitat evaluation system is considered almost sufficiently accurate, but for management application Test 1 and 2 R-squared values should be >= 0.75. This is likely possible with: more careful selection and analysis of training data; better spectral differentiation among coniferous tree species, and; improved methods of testing predicted ranks. Use of the more expensive thematic mapper imagery may help, but the only known application to evaluating white-tailed deer habitat had lower map accuracy than this study.

ACKNOWLEDGEMENTS

This project was funded by the Ontario Ministry of Natural Resources, and by Employment and Immigration Canada, through special employment programs. The Ministry of Natural Resources provided financial assistance for image acquisition and analysis, seasonal employees and field support, and eight months education leave for myself. In this regard I thank: Don Johnston, Regional Director, Northwestern Regional office, Kenora, and; John Cleaveley, Roy Brown, Ted Swift and Tim Taylor of the Fort Frances District office.

Many seasonal employees assisted in various stages of the project. These included: Kevin Begin, Scott Catherall, Linda Chepil, Ed Cousineau, Ken DeVos, Sean Douglas, Patty Fedoruk, Mel Galbraith, Gary Gilbert, Tina Grynol, Dianne Hoffman, Michelle Langlais, Jeff Maher, Laura Meades, Greg Penney, Martin Rittau, Stephanie Robinson, Jim Schaefer, Kurtis Scheirer, Steven Tetreault, Kevin Thornton and David Wolder.

Image acquisition and analysis were peformed by the Ontario Centre for Remote Sensing, Ministry of Natural Resources, Toronto. I thank staff members Andrew Jano and Jeff Overton for their expert work, advice and assistance. I thank Linda Needen and Linda Uin of the University of Manitoba, Jim Schaefer of Lakehead University, and Bill Dalton of the Ontario Ministry of Natural Resources, Thunder Bay, for assistance in computer programming.

The Fort Frances Sportsmens' Club, an affiliate of the Ontario Federation of Anglers and Hunters, acted as sponsor for portions of the field work funded as special employment projects by Employment and Immigration Canada. In this regard I particularly thank Jeff Johnston, past President.

I thank my PhD Supervisor, Dr. R.R. Riewe, and my advisory committee for their helpful advice: Drs. Roger Evans, Larry Stene and John Stewart of the University of Manitoba, and Richard Rounds of Brandon University.

Finally, I would like to thank my wife Deborah Cornell and our daughter Laura Darby, for their support, patience and understanding throughout this endurance test.

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1.0 INTRODUCTION

Maintaining a supply of suitable habitat is an important part of managing wildlife populations. One tactic for managing white-tailed deer (Odocoileus virginianus) on northern range is to manipulate the habitat into as near an optimal condition for deer as possible so that deer can better withstand and recover from severe winter weather. The deer population can then be managed for a desired size given carrying capacity of the habitat during years with favourable winters (Wallmo et al., 1977; Potvin and Huot, 1983). This approach puts emphasis on proactive rather than reactive management. In other words, the manager can influence the outcome of future events by manipulating habitat, rather than simply reacting to those events.

The first step in implementing such a tactic is to determine how well habitat of a given area compares to the optimal spatial distribution of important landform-vegetation categories, or 'biophysical themes'. The result of such an evaluation can be expressed by an ordinate ranking of habitat suitability on both a square kilometer (sq.km) and area-wide basis.

The Ontario Ministry of Natural Resources (OMNR) uses a set of provincial standards and guidelines for deer habitat evaluation based on an ordinate ranking system (OMNR, 1984a). However, the evaluation criteria require labour-intensive field-sampling or airphoto interpretation. Most OMNR district offices do not have the financial resources to conduct such labour-intensive evaluations, and the quality of deer management suffers.

A potential method of evaluating deer habitat is to use computer analysis of Landsat satellite imagery to predict habitat suitability rank for a given area. This might be accomplished by comparing a Landsat-derived spatial description of major biophysical themes, giving proportions of total area in each theme and an edge index, to optimal standards derived from the scientific literature. The output would be an average habitat suitability rank for the study area plus an array of habitat suitability ranks, each cell of the array representing one sq.km of the area. Would such predictions be accurate? This study attempts to provide an answer.

One study objective was to make predictions of habitat suitability for white-tailed deer on an ordinate scale from Landsat multispectral scanner (MSS) imagery. MSS imagery was used because of its low cost relative to thematic mapper (TM) data. A second objective was to assess accuracy of the predictions by testing the following hypothesis:

Ho: predictions of habitat suitability derived from an MSS thematic map of white-tailed deer habitat of minimum 75% accuracy, are significantly ($P<0.05$) correlated with independent measures of habitat mosaic suitability, deer forage, cover and site characteristics.

The map accuracy level of 75 % was arbitrarily chosen as a reasonable threshold for management application. The thematic map represented the mosaic of habitat types relevant to white-tailed deer, based on measurements of reflected light from the top of the forest canopy. Hypothesis acceptance required significant correlation of the predicted ranks with 'true' suitability of the habitat mosaic as determined by airphoto interpretation and ground data, and with ground measurements of important food, cover and site characteristics. The remote predictions were therefore assessed by correlation with measures relating directly to deer ecology.

2.0 LITERATURE REVIEW

2.1 Landsat

2.1.1 Landsat Technology

Landsat satellites have remote-sensing sub-systems that can distinguish broad landform and vegetation categories by their spectral reflectance values. The National Aeronautics and Space Administration (NASA) Landsat program began providing such data on July 23, 1972, with the launch of Landsat 1, formerly called Earth Resources Technology Satellite 1 (ERTS-1). Five Landsat satellites have been launched to date of which only Landsats 4 and 5 are still functioning (Table 1).

Table 1: Schedule of launch and deactivation dates for Landsat satellites.

Landsat	Launch Date	Deactivation Date
1	72.07.23	78.01.06
2	75.01.23	80.01.22
3	78.03.05	83.09.30
4	82.07.16	--------
5	84.03.01	--------

Descriptions of the Landsat satellites and their remote-sensing sub-systems were provided by Harper (1976), Short et al. (1976), Murphy (1979), NASA (1982) and Colwell et al. (1983). Lansing and Cline (1975) described the multispectral scanner (MSS) in detail, and NASA (1982) described the thematic mapper (TM). Harper (1976) briefly described the operation of a thermal infrared scanner.

All Landsat satellites operate in a circular near-polar sun-synchronous orbit (Harper, 1976). Landsats 1,2 and 3 advanced westward with each orbit scanning a 185 km swath of land so that a global cycle was completed when the entire earth's surface from 81 degrees north to 81 degrees south latitude was viewed. The MSS was the same on each satellite, consisting of an oscillating mirror coupled with a fibre optics array, filters and electro-optical detectors (Harper, 1976; NASA, 1982). As the satellite moved along a ground track the MSS swept back and forth across the swath, and with each forward sweep it simultaneously scanned six adjacent strips of pixels (picture elements). For each pixel it recorded the intensity of electromagnetic radiation from the earth's surface in four wavelength bands: green (0.5 to 0.6 um), red (0.6 to 0.7 um), photographic infrared (0.7 to 0.8 um) and near infrared (0.8 to 1.1 um) (Harper, 1976; Murphy, 1979). Landsat 3 operated at a nominal altitude of 918 km taking 18 days to complete a global cycle, thus repeating coverage for any given area every 18 days. Corrected pixel size was 59 x 79 m (Colwell et al., 1983).

Landsat 4 experienced failure of two of its four solar panels during the early stages of operation, and at present is operating at less than full capacity. Landsat 5 was launched ahead of schedule because of this problem and placed in a pursuit path of Landsat 4 with an 8 day delay.

Landsats 4 and 5 have both an MSS and TM. The four-band MSS on each is similar to those of previous Landsats, providing continuity of data acquisition with them, but the TM has many improvements over the MSS. The TM scans and obtains data in both directions, and its detector arrays are located in the primary focal plane allowing incident light to be reflected directly onto the detectors without transmission through fibre optics as with the MSS. Also, the TM operates in 7 spectral bands as outlined by NASA (1982:3):

-Band 1 (0.45 to 0.52 um) - for water body penetration and differentiation of soil from vegetation, and deciduous from coniferous flora;

-Band 2 (0.52 to 0.60 um) - for measuring green reflectance peak of vegetation for vigor assessment;

-Band 3 (0.63 to 0.69 um) - a chlorophyll absorption band important for vegetation discrimination;

-Band 4 (0.76 to 0.90 um) - for determining biomass content and delineating waterbodies;

-Band 5 (1.55 to 1.75 um) - for detecting moisture content of vegetation and soil, and for differentiation of snow and clouds;

-Band 6 (10.40 to 12.50 um) - a thermal infrared band for vegetation stress analysis, soil moisture, and thermal mapping;

-Band 7 (2.08 to 2.35 um) - for discriminating rock types and hydrothermal mapping.

The MSS's of Landsat 4 and 5 also have a corrected pixel size of 56 x 79 m (Jensen, 1986) despite the fact orbital altitude of the satellites was reduced to 705 km so that resolution of the TM could be improved to a 30 x 30 m pixel. Band 6 has a larger pixel size of 120 x 120 m. In addition, the TM scans 16 strips of pixels with each mirror sweep for bands 1 to 5 and 7, and four for band 6 (NASA 1982).

All Landsat satellites collect radiance data continuously and transmit it in digitized form to a ground receiving station where the data are stored on computer compatible tapes (CCT's). Canadian receiving stations are at Prince Albert, Saskatchewan, and Shoe Cove, Newfoundland. The data are corrected for radiometric and geometric errors before analyses are performed (Murphy, 1979).

Markham and Barker (1983) compared MSS spectral response curves and simulated mean outputs for field reflectance data of all five Landsats. They found that Landsats 4 and 5 were essentially identical in mean spectral response, and the spectral differences between them and previous scanners were usually small and comparable to variability among the latter.

2.1.2 Multispectral Image Analysis

There are two principal methods of digital multispectral image analysis: classification and image enhancement. Alfoldii (1978) provided an excellent self-teaching introduction to the first, based on the Canada Centre for Remote Sensing (CCRS) Image Analysis System (CIAS) (Goodenough, 1979). He explained that CCT's store light intensity data in each wavelength for all pixels. The particular combination of intensity levels in different wavelengths for any one pixel is called the 'spectral signature' of that pixel. Analysis of a multispectral image is based on classifying pixels by their spectral signatures with either supervised or unsupervised techniques (Goldberg and Shlein, 1976; Johnston and Howarth, 1980) (Table 2).

Supervised classification means the computer programmer and a manager familiar with the study area, dictate or 'supervise' the imagery classification. This is done by selecting 'training areas' that represent homogeneous examples of relevant biophysical themes. Light reflected from pixels of the training areas for a given theme is analyzed with the computer to define the spectral signature of each theme of interest (eg. mature deciduous forest). When a simple range of light intensities in each wavelength band is used, the result is an n-dimensional 'rectangular parallelepiped' signature. More accurate procedures are to employ a 'minimum distance classifier', or a 'maximum likelihood program'. The

Table 2: Advantages and disadvantages of supervised and unsupervised classification procedures (adapted from Campbell, 1987).

	Supervised	Unsupervised
Advantages:	- image analysed for environmental features relevant to the study; - final map production simplified; - allows comparison with classifications from other dates and areas; - may detect errors in classes by examining training areas on thematic map.	- classes are spectrally homogeneous compared to supervised classes; - chance of human error is minimized; - unique spectral classes not incoporated into other classes, causing errors; - no prior knowledge of area needed; - map applies to many issues & species.
Disadvantages	- training areas may not represent scene-wide spectral variability; - ground truthing is likely necessary. - classification imposed may not be spectrally 'natural' causing errors.	- classes defined may not represent environmental features of interest; - extensive field investigation required to interpret classes; - spectral properties of classes change over time & classification can't be applied to other areas and times.

minimum distance classifier determines the spectral coordinates for each theme, called 'centroids', in n-dimensional feature space and assigns pixels to the theme with closest centroid. The maximum likelihood program assigns each pixel to a theme that maximizes likelihood of a correct classification, given spectral means and variability in the training data (Phillips and Swain, 1973; Alfoldii, 1978; Campbell, 1987).

Unsupervised classification allows the computer to delineate natural groupings of spectral values within a scene and map them as information classes. These spectrally similar areas are identified by a clustering algorithm that separates statistically cohesive clusters of spectral coordinates in feature space; such clusters have different spectral signatures (Alfoldii, 1978). A digital grey-tone or colour-coded map is then printed showing the goegraphic location of pixels in each spectral category, and the investigator must determine the environmental significance of each category in the field.

The second major method of Landsat image analysis, image enhancement, involves transforming digital MSS data into reflectance units, with atmospheric and illumination correction, then contrast stretching the units between fixed reflectance limits. Ahern et al. (1982) gave the details of this process, and Ahern (1983) outlined three enhancement products available from CCRS.

A major limitation of classifying biophysical characteristics with MSS data from one date is that different terrain or vegetation features are often best separated at different times of the year because of phenological or moisture differences. Schreier et al. (1982) used multi-date imagery to enhance contrast between biophysical categories and improve their classification for predicting off-road mobility conditions in northern Manitoba. Byrne et al. (1980) assessed the value of using imagery from two dates to monitor land-cover changes in New South Wales, Australia. Other studies using multi-date imagery were McGinnis and Schneider (1978), Thomas et al. (1978) and Fisher et al. (1979).

2.1.3 Thematic Map Accuracy Assessment

Hay (1979) points out the distinction between errors of prediction associated with the thematic map, and errors not associated with it. For example, problems in matching sample sites on imagery with exact locations in the field may lead to apparently incorrect predictions which are in fact sampling artifacts. Also, the time interval between prediction and field survey may result in changes recorded as errors of prediction. Published estimates of accuracy usually assimilate such errors.

A common standard for acceptable average accuracy of thematic maps is 85% (Anderson et al., 1976; VanGenderen and Lock, 1977;

Fitzpatrick-Lins, 1981; Aronoff, 1982a). Several sampling designs have been employed for estimating accuracy, and most authors use a contingency table to evaluate errors of commission (identifying a class as A when it is in fact not A) and omission (identifying a class as something else when it is really A). Stow and Estes (1981) used systematic random sampling with 0.4 ha sampling units and airphotos as ground truth; average accuracy of their map was 73 ± 5 % ($P<0.05$). Todd et al. (1980) used cluster sampling with sampling units of 3 x 3 pixels. Three types of error caused their themes to vary in accuracy from 9.1 ± 18 % to 97.3 ± 1.4 % ($P<0.05$) (average accuracy calculated to be 83.7 %). Firstly, analysts' definitions of resource classes caused problems that accounted for 45 to 55 % of total error. Secondly, 35 to 45 % of total error was due to mapping themes whose spectral characteristics approached and sometimes exceeded the noise level. Thirdly, geometric and radiometric residual errors accounted for 5 to 15 % of total error, mainly due to errors of ± one pixel in aligning imagery and air photos.

Fitzpatrick-Lins (1981), Rosenfield et al. (1982) and Card (1982) criticized assessments made with simple or systematic random sampling because these methods tend to oversample high-frequency themes and undersample low-frequency ones, causing wide confidence intervals and evaluation problems. The data of Todd et al. (1980) showed that the same difficulty can arise with cluster sampling. To compensate for this, Hay (1979) recommended a stratified sampling design with themes as strata and a minimum of 50 observations in each theme. In this design sampling sites are chosen randomly over the entire map area, rejecting assignments to strata once their requirement is filled, until all strata are adequately sampled. This method permits identification of underestimation, overestimation and significant misclassification between themes by using simple tests based on the binomial distribution and its poisson approximation. However, both Hay (1979) and Card (1982) pointed out that for stratified random sampling "the proportions-correct, given the true category, should not be estimated by the diagonal entry divided by the row sum, because of bias introduced by possible differential sampling rates within map categories" (Card, 1982:433). Card (1982) proposed a method for correcting such bias using map category marginal proportions to produce unbiased estimates of proportions-correct given the true category.

Rosenfield et al. (1982) pointed out the difficulty of manually selecting and locating sample points in sparse map categories when using stratified random sampling. In fact, Fitzpatick-Lins (1981) found that although stratified systematic unaligned sampling (Rosenfield et al., 1982) could be applied manually, with an undersampling of sparse categories, computer automation was required to take an additional stratified random sample of sparse themes. Rosenfield et al. (1982) also pointed out the need to area-weight the average accuracy estimate when additional sampling is conducted.

A different approach was suggested by Ginevan (1979) who recommended use of acceptance sampling and the binomial probability density function. Using a FORTRAN program, Ginevan developed tables that give optimal sample size and critical value levels for map rejection, for different levels of "Consumer's Risk" (probability that a map of unacceptable accuracy will pass the accuracy test) and "Producer's Risk" (probabiltiy that a map of acceptable accuracy will be rejected). Aronoff (1982b) elaborated on the theory, and Aronoff (1982a) provided a method for using the technique to assess overall map accuracy, accuracy of individual themes, and interpretation of results. He suggested simple random sampling with an additional stratified random sample of sparse categories, as did Hay (1979). Aronoff's (1982a) method optimizes cost-benefit considerations of sampling and has the interpretation advantages of other techniques described herein. He does not, however, correct for differential sampling rate bias when assessing map accuracy.

2.1.4 Forestry and Wildlife Applications

Numerous investigators have used Landsat digital data for forest inventory applications. Most have been able to achieve 74 % or greater accuracy in mapping generalized classes such as conifer and deciduous stands, cutovers and conifer regeneration (Heath, 1974; Kirby et al., 1975; Dodge and Bryant, 1976; Lee, 1977; Rubec and Wickware, 1978). Attempts to derive more detailed classifications have met with variable results.

Pala and Jano (1981) felt that classes specified by species composition, age and volume cannot be reliably defined on the basis of satellite data alone. Beaubien (1979) used unsupervised classification of Landsat MSS imagery to map species composition and maturity of Quebec forests. Classification of the relatively simple boreal forest of Anticosti Island was satisfactory, but on the Laurentian plateau only hardwood, mixedwood and two or three types of softwood could be accurately mapped. Beaubien did not find it possible to distinguish regenerating from mature stands of mixedwood and hardwood.

Beaubien (1980) was successful in using principal component enhancement to achieve a generalized classification of boreal coniferous and subarctic vegetation near the southern Labrador-Quebec border. He also found that supervised classification was more useful than colour enhancement or unsupervised techniques in distinguishing certain ground-cover types.

Mayer and Fox (1981) (see also Fox et al., 1983) classified forest stands in California by conifer species, canopy density and crown diameter with 83 % accuracy for species, size and density, and 88 % accuracy for species alone, relative to errors of omission. They used controlled clustering to define resource spectral signatures from training sites, and unsupervised classification to identify other unique spectral signatures located elsewhere. Resource labels were assigned to spectral curves for unknown classes by comparison with signatures for known classes, signatures were pooled or deleted, and the resultant pooled signatures were used to delineate 16 themes.

Walsh (1980) used controlled clustering classification in Oregon to map 12 surface-cover types of which 7 were coniferous tree species. Using ground-truthing and sample units of 5 x 5 pixels, he determined average accuracy to be 88.8 %, but he ignored errors of omission. The major environmental factors affecting classification were degree and aspect of slope, surface-cover variability, crown size and crown density (cf. Beaubien, 1979).

Hopkins et al. (1988) did a preliminary assessment of thematic mapper data for forestry application on two small sample areas in Wisconsin. They found overall thematic map accuracy to be 85 % in an area of 6003 pixels that included agricultural lands in southeastern Wisconsin. In this area average accuracy for detailed forest species classes was 69 %. Overall accuracy improved to 97 % when the number of map themes was reduced to six by merging. All reports of accuracy were based on errors of omission with no correction for differenial sampling rate bias (Card, 1982). In the second sample area, 1655 pixels of forest in northwestern Wisconsin, overall map accuracy of 93 % was achieved for 11 generalized land use classes, but only after lowlands were manually differentiated from upland conifer during programming, and after clearcut and defoliation classes were considered to be softwood for purposes of accuracy assessment.

Wildlife applications of Landsat imagery began to appear in the literature after NASA selected and funded over 300 multidisciplinary investigations to utilize ERTS data (Lent and LaPerriere, 1974; LaPerriere, 1976; Work and Rebel, 1976). Colwell et al. (1978) used multi-date Landsat MSS data to assess and monitor temporal changes in waterfowl habitat suitability in the prairie pothole region of North Dakota. The number of ponds was mapped by level slicing the MSS 0.8 to 1.1 um waveband. Landsat estimates of pond number paralleled field estimates of the US Fish and Wildlife Service but were 56 to 88 % lower because most of the ponds were less than 0.4 ha (1 pixel) in size. The authors developed a preliminary model for evaluating habitat suitability on the basis of water conditions and terrain characteristics quantified from MSS imagery. Accuracy of the final model and thematic maps was not assessed quantitatively, but the model was judged by the authors to be worthy of further development.

Wyckoff (1980,1981) analysed mule deer (Odocoileus hemionus) population trends in central Utah with state pellet group data and range area data extracted from multi-date Landsat MSS imagery. Available winter range was determined by subtracting seasonal distribution (presence/absence) of snowcover from vegetationally suitable areas as mapped from imagery. Range area accounted for a large proportion of the year to year variability in pellet group data (r=-0.83).

In Alaska, LaPerriere et al. (1980) successfully employed a modified clustering technique to produce line-printer maps of Landsat spectral classes for analysis of moose (Alces alces) habitat. Vegetation data were collected by aerial and ground sampling, and vegetationally similar spectral classes were grouped into 11 moose habitat classes. An accuracy assessment of the resultant thematic map was not made. Similarly, Thompson et al. (1980) used MSS imagery to map major habitat types of barren-ground caribou (Rangifer tarandus groenlandicus) in the Keewatin Region, Northwest Territories. They used a migrating means clustering algorithm and unsupervised classification to delineate spectrally similar sampling units. Within each unit they determined the proportion of 8 major vegetation cover types, and four major vegetation complexes resulted. Caribou use of cover types and vegetation complexes was quantified by pellet group survey.

Horn (1981), and Dixon and Horn (1981), reported results for vegetation mapping of barren-ground caribou winter range in northern Manitoba using principal component colour enhancement of MSS imagery. Overall accuracy was not determined because of sampling difficulties, but accuracy at one test site was better than 81 % for 6 of 8 image colours with respect to commission errors, and for 7 of 8 with respect to omission errors. At another site confusion occurred because the same colours were used to delineate themes across an ecological gradient between tundra and subarctic forest (Dixon and Horn, 1981). Horn (1981) did a cursory habitat evaluation of the area based on analysis of the imagery. He reported approximately 25 % of the area as prime habitat, 35 % as satisfactory, 15 % marginal and 10 % unsatisfactory. Water bodies covered 15 %.

Bowles et al. (1984) used an unsupervised classification of MSS imagery to stratify approximately 3,700 sq.km of moose habitat in north-central Manitoba for aerial moose inventory. Map accuracy was assessed using forest resource inventory maps as truth for four townships, approximately 10 % of the area. Overall map accuracy for six generalized themes was 84 % based on errors of omission and no correction for differential sampling rate bias.

Cannon et al. (1982) evaluated habitat of lesser prairie chicken (Tympanuchus pallidicinctus) in western Oklahoma. They found correlations between density of displaying males and Landsat-generated resource classes that paralleled similar relationships determined by field sampling.

The only studies applying Landsat imagery to white-tailed deer encountered during this review were Boyd et al. (1981) and Ormsby and Lunetta (1987). Boyd et al. stratified habitat for aerial survey of mule and white-tailed deer in Alberta by supervised classification of MSS imagery. Their technique assigned ranks of 1 to 8, representing probable use by deer, for each sq.mi. (2.56 sq.km) of two study areas (2,400 and 1,000 sq.km in size). Ranks were based on a set of criteria that combined Landsat-derived biophysical categories into priorized habitat types. They did not report any quantitative assessment of accuracy for the resultant habitat ranks.

Ormsby and Lunetta (1987) used an unsupervised classification of Landsat 4 TM data to produce a land cover map for a 194 sq.km area of lower Michigan. These data were combined with digitized ground data, using Geographic Information System (GIS) software, to develop a white-tailed deer food availability map. Their map depicted areas of potential food availability (agricultural crops) based on a land cover's food value and distance from escape cover. They reported an average accuracy for the land-cover map of 73% with six themes and 67% with 10 themes. In both cases reported accuracy was based on errors of omission with no correction for differential sampling rate bias. Accuracy of their final food cover map was not reported.

The most comprehensive evaluation of wildlife habitat using Landsat was performed by Craighead et al. (1982) for grizzly bears (Ursus arctos) in western Montana. Craighead et al. first conducted ground investigations and developed a landform-vegetation map, zoned by altitude, for the study area. They then quantified bear food habits and food resources within the different altitudinal zones. The landform-vegetation map was used to delineate training sites for supervised classification of MSS data, and a thematic map was developed. They reported (p.147:Table4) average accuracy of this map to be 88.6 % based on errors of omission and nine themes. Spectral signatures for the primary area were extrapolated to two secondary study areas to produce thematic maps. Accuracy of those maps was determined to be 75.2 % and 74.6 %. Craighead et al. found that boundaries between habitat categories were not discrete and many pixels along boundaries were misclassified as other categories with intermediate spectral signatures. When these 'ecotonal' pixels were considered correct, average accuracy for the primary and two secondary study areas increased to 93.2, 90.5 and 85.0 % respectively. Finally, Craighead et al. related quantitative estimates of food resources in different landform-vegetation categories to the ecospectral classification to rate more generalized vegetation complexes by abundance of specific food plants.

2.2 Deer and Their Habitat

2.2.1 Food Habits of White-tailed Deer

Lists of forage species importance for white-tailed deer are dissimilar for different parts of North America, but similarity increases for lists compiled within the same forest type (Table 3, cf. Huot, 1974 and Wetzel et al., 1975). Yet within a forest type, importance lists for deer in adjacent areas can differ due to regional differences in plant species abundance, soil, topography, agricultural influences and snowcover (Table 3, cf. Mooty, 1976, and Kohn and Mooty, 1971 versus Wetzel et al., 1975 and Garrod et al., 1981). Thus, as Medin (1970) pointed out, caution must be used in transferring food habit information from one area to another.

Methods of food habit study for white-tailed deer have traditionally fallen into one of four categories:

(1) rumen analysis (Aldous and Smith, 1938; Korschgen, 1962; Chamrad and Box, 1968; Drawe, 1968; Coblentz, 1970; Nixon et al., 1970; Kohn and Mooty, 1971; McCaffery et al., 1974; Korschgen et al., 1980; Garrod et al., 1981);

(2) observation of feeding sites or browsed twigs (Hamerstrom and Blake, 1939; Nixon et al., 1970; Kohn and Mooty, 1971; Huot, 1974; Wetzel et al., 1975; Mooty, 1976; Gates and Harman, 1980);

(3) observation of wild deer either captive or free-ranging (Hamerstrom and Blake, 1939; Kohn and Mooty, 1971; Skinner and Telfer, 1974), and;

(4) observation of tame deer (Dunkenson, 1955; Healy, 1971; Stormer and Bauer, 1980; Crawford, 1982).

Table 3: Some important forage species for wild white-tailed deer in different geographic and forest regions.

	Important forage species[1]			
Geographic Region	S.E. Manitoba	N.C. Minnesota	N.E. Minnesota	Quebec
Forest Region[2]	Gt.Lakes-St.Lawrence	Gt.Lakes-St.Lawrence	Gt.Lakes-St.Lawrence	Gt.Lakes-St.Lawrence
Reference	Garrod et al. (1981)	Mooty (1976), Kohn and Mooty (1971)	Wetzel et al. (1975)	Huot (1974)
Method & (n)	Rumen analysis (14)	Feeding Sites (163)	Feeding Sites (132)	Browse counts (605plots)
Autumn (A)&/or Winter (W)	(A & W) Gramineae Linum sp. Rosa sp. Pteridophyta Cornus stolonifera Sonchus sp. Epilobium angustifolium Abies balsamea Salix sp. Rudbeckia spp. Musci Viburnum spp. Bromus spp. Pinus sp.	(W) Corylus cornuta Amelanchier spp. Alnus crispa Pinus banksiana Vaccinium spp. Betula papyrifera Ledum groenlandicum Salix spp. Pinus strobus Pinus resinosa Populus tremuloides Gaultheria procumbens Prunus spp. Lonicera spp.	(W) Acer spicatum Amelanchier spp. Acer rubrum Cornus rugosa Cornus stolonifera Populus tremuloides Corylus cornuta	(W) Corylus cornuta Acer spicatum Acer saccharum Lonicera canadensis Acer rubrum Cornus stolonifera Viburnum alnifolium Betula papyrifera Thuja occidentalis Alnus rugosa Ostyra virginiana Fagus grandifolia Picea spp.
Spring (SP) &/or Summer (S)		(S) Corylus cornuta Aster macrophyllus Trifolium spp. Populus tremuloides Betula papyrifera Salix spp. Impatiens biflora Acer spicatum Diervilla lonicera Aster spp. Prunus spp. Acer rubrum Fragaria virginiana Amelanchier spp.		

. . .continued

Table 3: Some important forage species (continued).

	Important forage species[1]			
Geographic Region	New Brunswick	Wisconsin	Missouri	Texas
Forest Region[2]	Gt.Lakes & Acadian	SAF[2] 14-18, 21-27, 36-37 & 39, & oak-hickory	Oak-hickory	
Reference	Skinner & Telfer (74)	Hamerstrom & Blake (39) McCaffery et al. (74)	Korschgen (1962) Korschgen et al. (80)	Chamrad & Box (1968) Drawe (1968)
Method & (n)	Rumens (54) & (12)	Rumen analysis (76) Feed Sites & Obs.	Rumen analysis (235) & (304)	Rumen analysis (60) & (16)
Autumn (A) &/or Winter (W)	(A) Pyrus malus Fagus grandifolia Thuja occidentalis Comptonia peregrina Gaultheria procumbens Abies balsamea Polyporus arcularius Usnea sp.	(W) Gaultheria procumbens Myrica asplenifolia Populus grandidentata Pyrus melanocarpa Quercus spp. Rubus villosus Salix spp. Vaccinium sp. Agropyron repens Amelanchier sp. Betula primila Cornus spp. Corylus americana	(W) Quercus spp. Zea mays Symphoricarpos sp. Rhus copallina Antennaria sp. Leopedeza stipulacea Triticum aestivum Forbs Gramineae Juniperus virginiana Glycine max Gleditsia triacanthos Rhus glabra	(W) Clematis drummondii Stipa leucotricha Allium spp. Nothoscordum bivalve Phyla incisa Malvastrum aurantiacum Mimosa strigillosa Bromus willdennorvii Limnodea arkansana Hybanthus verticillatus Lythrum californicum Rhynchosia americana Geranium carolinianum
Spring (SP) &/or Summer (S)	(S) Prunus virginiana Pyrus malus Prunus serotina Viburnum cassinoides Populus tremuloides Acer rubrum Rubus spp. Crataegus spp. Maianthemum canadense Geum spp. Fungi	(S) Populus sp. Gramineae Waldsteinia sp. Aster sp. Diervilla sp. Fragaria sp. Prunus sp. Quercus sp. Gaultheria sp. Trifolium sp. Agaricaceae Acer sp.	(SP & S) Vitis aestivalis Trifolium pratense Parthenocissus sp. Lespedeza stipulacea Vitis vulpina Ulmus americana Rhus copallina Rhus aromatica Lactuca Scariola Ulmus rubra Vitis riparia Lactuca canadensis	(S) Opuntia lindheimeri Acacia farnesiana Desmanthus virgatus Commelina erecta Zanthoxylum fagara Cyanchum barbigerum Gerardia heterophylla Solanum spp. Ambrosia parlostachya Machaeranthera tenuis Aster subulatus Acalypha radians

[1] Ranked in descending order of importance.

[2] Rowe (1972) and Society of American Foresters (see McCaffery and Creed 1969)

Various sources of bias exist with each method, but only the main ones will be mentioned here. Rumen analysis, observation of feeding sites and browsed twigs, and observation of wild deer, tend to underestimate the importance of herbaceous material, especially small highly digestible forbs (Bergerud and Russell, 1964; Scotter, 1966; Vangilder et al., 1982). Captive wild deer are restricted in their choice of habitat and food, or are exposed to an environment artificially altered by high deer densities (Coblentz, 1970; Hubert et al., 1980). Biases that may affect the forage preferences of tame deer are the amount of prior foraging experience (Bartmann and Carpenter, 1982) and the fact that tame deer are often maintained on artificial feed between foraging trials (Crawford, 1982). Regelin et al. (1976) and Bartmann (1982) compared food habits of tame mule deer with and without supplemental feed. Regelin et al. found forage preferences were similar for the two groups, whereas Bartmann found differences that appeared to be affected by conditioning to the area rather than by artificial feeding. Healy (1971) found that tame and wild white-tailed deer had similar forage preferences.

Recently, microhistological techniques have improved the accuracy of rumen analysis (Sparks and Malechek, 1968; Vavra and Holechek, 1980). The main advantage is that digestion has less apparent effect on discernibility of microscopic identifying characteristics of forage than on gross structure (Johnson et al., 1983); hence highly digestible forages are more readily identified.

Unfortunately, inadequate observer experience is a major source of error with this technique (Holechek et al., 1982). At least four weeks of intensive training are required as well as an extensive reference collection of histological specimens, drawings, photographs and keys of epidermal material (Holechek and Gross, 1982).

It appears that the most cost-effective method of estimating forage preferences of deer is still volumetric and point-frame analysis of rumen contents (Robel and Watt, 1970; Korschgen, 1980). Ward (1970) and Medin (1970) reviewed techniques and literature on the subject. Medin considered minimum sample size to be 100 with a larger sample required for estimating seasonal changes in diet. He questioned whether samples from animals dying of different causes were unbiased, but pointed out that Leach (1956) found little difference in percentage composition between samples from winter-killed deer and deer collected by shooting.

McCaffery et al. (1974) used rumen samples from road-killed deer. They considered use of roadsides by deer to be an expression of preference rather than bias, because McCaffery and Creed (1969) found that peak frequency of road-kills and right-of-way use by deer coincided with use of other openings and fields containing similar vegetation.

2.2.2 The Concept of Carrying Capacity

The concept of carrying capacity was developed when Lotka (1925) and Volterra (1926) used the logistic curve to describe the idea that population growth is limited to a maximum density of animals that can be sustained by a given habitat. Edwards and Fowle (1955:597) reviewed literature on the subject and stated that "for practical purposes we may regard carrying capacity as represented by the maximum number of animals of a given species and quality that can in a given ecosystem survive through the least favorable environmental conditions occurring within a stated time interval. ... usually one year." Caughley (1979) put emphasis on the number and quality of both animals and plants. Edwards and Fowle (1955) stressed that carrying capacity is not a stable property but a result of the many interactions between organisms and their environment.

Moen (1973) developed a hypothetical model for estimating carrying capacity based on protein and energy requirements (cf. Mautz, 1978). Hobbs et al. (1982) successfully used an energy and nitrogen-based model modified from Mautz (1978) to estimate carrying capacity of elk winter range in Colorado.

Certainly, the quantity and quality of forage is fundamental to the ability of an area to support white-tailed deer (Klein, 1970), especially since deer are more tolerant of adverse winter weather when high quality food is available (Moen, 1968, 1976).

But in northern range, deep snow can make high quality forage unavailable, and severe winter weather is often a major mortality factor (Karns, 1980; Potvin et al., 1981). Snowcover, topography and protective cover are other important factors that should be considered in any evaluation of habitat or carrying capacity (Telfer, 1967, 1978; Moen, 1968; Ozoga and Gysel, 1972; Drolet, 1976; Kucera, 1976; Armstrong et al., 1983a).

The question arises, should a habitat evaluation procedure be based on a measure of carrying capacity? Two studies are pertinent; both incorporated snow effects and one incorporated cover. The first was by Wallmo et al. (1977) who related seasonal protein and energy supplies in native forage to seasonal requirements of mule deer, to determine carrying capacity of a study area in Colorado. They found that, based on forage quantity, the range could support large numbers of deer during all seasons, but based on forage quality it could not support any deer during winter. For example, deer were hard pressed to meet their maintenance requirement of 7 % crude protein because forage consumed had an average crude protein content of 5 %, even allowing for protein selection. Protein and energy shortfalls were made up by fat hydrolysis and protein catabolism. Wallmo et al. (1977:126) concluded that "the concept of a stable carrying capacity for deer in the high valleys of the central Rockies is unrealistic".

The second significant study was by Potvin and Huot (1983) who estimated carrying capacity of a white-tailed deer wintering area in Quebec. They delineated cover types of a 19 sq.km area and measured browse production and nutritive content by cover type. They then related nutritional value of browse available above the snow to deer requirements and the energy cost of walking through the snow. Assuming a maximum sinking depth, they found that deer could maintain a positive energy balance with all browse types at 50 cm snow depth, but at 75 cm only the most productive browse types allowed this, and at 100 cm deer could not maintain a positive energy balance on any browse type. Depending on whether sinking depth was maximum or 25 cm, estimated carrying capacity for a severe winter was 0 to 18 deer/sq. km, respectively. Potvin and Huot concluded that the concept of a stable carrying capacity was unrealistic and that periodic severe winters can act independently of deer density to prevent overuse of the range (cf. Ransom, 1967; and Kucera, 1976).

Obviously, there are problems in applying a simplistic definition of carrying capacity. Why don't all deer in a wintering area die if carrying capacity falls to zero? The answer lies in the physiological adaptations of white-tailed deer to winter. Deer survive winter by lowering their metabolic rate to a reduced fasting level, a level below maintenance requirements, which allows them to exist on reduced rations (Silver et al., 1969, 1971). Moen (1978) desribed the seasonal nutrient requirements of deer as a sine wave reaching its apex in summer and nadir in winter (see also Ozoga and Verme, 1970). When nutrient intake is less than maintenance requirements, deer supplement intake through fat and tissue protein catabolism (Anderson et al., 1972; Mautz et al., 1976; Swick and Benevenga, 1977; Karns, 1980). Thus, as Karns (1980:51) stated, "physiological adaptation of white-tailed deer to the seasonal weather pattern is an annual metabolic rhythm that assures survival through most years. Occasional severe winters exceed these physiological limits, resulting in overwinter mortality".

The relationship of habitat and extrinsic mortality factors to population dynamics was best described by Potvin et al. (1981:84) citing Huffaker and Messenger (1964): " it is probable that the importance of the density-dependent [limiting] factors [e.g. food] decreases as the environmental conditions become more variable and the favorable microhabitats are more scattered".

It is important that high quality food be available during summer through early winter, and in early spring, for deer to build up reserves and recover physiological losses, respectively. Advancements in our understanding of deer physiology have caused managers in northern deer range to put more emphasis on summer habitat and forest openings than they did previously (McCaffery and Creed, 1969; Rutske, 1969; Byelich et al., 1972; Euler, 1979; McCaffery et al., 1981).

Thus, it appears a sound management strategy for maximum sustained yield, is to manipulate habitat into as near an optimal condition for deer as possible, then maintain population size at a level coincident with inflection point of the population growth curve given carrying capacity of the habitat during years with favorable winters. Adjustment for extrinsic mortality factors such as severe winter weather, predators, and legal and illegal harvest, can be made on an *ad hoc* basis. This approach puts emphasis on proactive rather than reactive management. A management objective of optimizing viewing and sustained yield would necessitate maintaining deer population size somewhat above inflection point of the population growth curve.

Hence, the answer to our previous question is yes, an evaluation procedure should be based on a measure of carrying capacity, because eventually an estimate of inflection point of the population growth curve is required. However, the first step is to determine how well the habitat compares to an optimal spatial mosaic of suitable landform-vegetation categories. The result of such a comparison could be expressed by ranking the habitat of each sq.km on a scale of 1 to 5, with one being optimal and 5 being unsatisfactory. Subsequently, carrying capacity could be calculated for each habitat rank based on: deer food habits and nutrient requirements; forage quantity, quality and availability; and weather/snowcover effects assuming a favourable winter.

2.2.3 Optimal Deer Habitat

Most studies of white-tailed deer habitat have looked at summer and winter range separately (Telfer, 1970; Kohn and Mooty, 1971; Wetzel et al., 1975; Stocker and Gilbert, 1977; Potvin and Huot, 1983). Indeed, some deer have been shown to move up to 40 km between summer and winter range (Rongstad and Tester, 1969; Verme, 1973; Drolet, 1976; Nelson and Mech, 1981).

Movement to winter habitats begins with an increase in snow depth and windchill values (Verme and Ozoga, 1971; Ozoga and Gysel, 1972; Drolet, 1976). In short, optimal winter habitat in northern deer range is any area of moderate elevation having a moderate to high proportion (10-60%) of softwood or mixedwood forest 10-20 m high, with a patchy conifer crown closure of 50 to 80 %, interspersed with small (less than 50 ha) stands of early successional deciduous or mixedwood species 1-10 m high with a conifer crown closure of less than 50 % (Table 4). Topography should include ridges with southerly aspects, soils should be fertile, and patchy openings within the softwood forest should have an abundance of preferred browse (Table 3).

Optimal summer habitat should be more diverse with more interspersion of types. There should be moderate to high representation of early successional shrubs, intolerant and tolerant hardwoods and mixedwoods with stand height 1-10 m and conifer crown closure <30 % (Table 5). Some mature hardwoods and mixedwoods should be present with herbaceous openings less than 2 ha in size comprising 3 to 15 % of the area (Table 5). Stocker and Gilbert (1977) stated that all locations should be less than 1500 m from open shallow water, and ridges with southerly aspects should be available. McCaffery and Creed (1969) felt that sandy soils provided better interspersion of habitat types and a predominance of intolerant hardwoods which are more beneficial for deer than tolerant species. However, openings were more productive on fertile loams.

Euler (1979) summarized the characteristics of optimal deer habitat for total range on a year-round basis. He stated that northern range should contain 5 to 15 % herbaceous openings 0.2 to 2.0 ha in size, and 30 to 60 % of the range should be early successional forest, such as regenerating clearcuts less than or equal to 50 ha in size, with uncut buffer zones between cuts. In aspen areas a rotational cutting plan was suggested with 25 % of each 100 ha block being cut every 10 years. Mature coniferous forest should comprise 10 to 30 % of the range, and food and shelter should be in close proximity to each other. Smith and Borczon (1981) provided several cutting plans for interspersing food and cover in cedar swamps.

Table 4: Characteristics of optimal winter habitat and their value for white-tailed deer.

Habitat Characteristic	Value for Deer	Citation[a]
1. Moderate to high proportion of conifer (10-60% of area, 55-100% of trees) $\geq$ 11m high, crown closure 60-80%, basal area 30-65 sq. m/ha	protection from deep snow & weather, night bedding, travel, escape cover, gestation	1,2,5,7,9, 10,11,12,13, 14,17,18,19, 20,22,25,27
2. Small (less than 2 ha) patches or strips of preferred browse in conifer stands	food, insolation	3,4,7,9,13, 14,17,20,22, 25
3. Ridges with S, SE or SW aspect and moderate elevation	protection from deep snow and windchill, insolation, food, day bedding, travel, gestation	7,13,14,20, 23,25
4. Regenerating clearcuts (less than or equal to 50 ha in size) of deciduopus & mixedwood species 1-10 m high, crown closure less than 50 %, interspersed with conifer stands	food, day bedding	5,6,7,8,9, 13,14,15,21, 22,26
5. High degree of interface (edge)	food, night bedding, day bedding, escape cover, gestation	4,7,9,10,13, 14,16,21,22, 23,24
6. Fertile soil	food, shelter	14,25

[a]: Numbers correspond to numbered references as follows:
1-Davenport et al. (1953); 2-Gill (1957a in Hall, 1984); 3-Gill(1957b); 4-Hepburn (1968); 5-Telfer (1970); 6-Byelich et al. (1972); 7-Huot (1974); 8-Telfer (1974 in Hall, 1984); 9-Wetzel et al. (1975); 10-Drolet (1976); 11-Kearney and Gilbert (1976); 12-Moore and Boer (1977); 13-Smith and Borczon (1977); 14-Stocker and Gilbert (1977); 15-Drolet (1978); 16-Telfer (1978); 17-Euler (1979); 18-Euler and Thurston (1980); 19-Gates and Harman (1980); 20-OMNR (1984a); 21-Tomm et al. (1981); 22-Armstrong et al.(1983a); 23-Armstrong et al. (1983b); 24-Potvin and Huot (1983); 25-Weber et al. (1983); 26-Sweeney et al. (1984); 27-Lang and Gates (1985).

Table 5: Characteristics of optimal summer habitat and their value for white-tailed deer.

Habitat Characteristic	Value for Deer	Citation[a]
1. 3-15 % of area in herbaceous openings less than or equal to 4 ha in size near conifer wintering area or in intolerant hardwoods	food, travel, night bedding, lactation, weaning	1,2,3,4,5,8, 9,13,14
2. Moderate to high proportion (15-55% of area) of early successional shrubs, intolerant and tolerant hardwoods & mixedwoods, 1-10 m high, conifer crown closure <30 %, clearcuts less than or equal to 50 ha	food, escape cover, day bedding, parturition, weaning, breeding	1,2,3,4,6,7, 8,9,10,12, 13,14,15,16
3. Some mature hardwoods & mixedwoods, stand height 10-20 m, conifer crown closure 30-50 %	food, escape cover, lactation	3,5,6,7,8
4. High degree of interface (edge)	food, escape cover, night and day bedding, travel, lactation, weaning	3,14,15,18
5. All locations <1500 m from open water	food, lactation, weaning, breeding, protection from insects	8,11
6. Some ridges with S, SE or SW aspects	night bedding, protection from insects, gestation	8
7. Generally sandy soils with fertile loams in areas of openings and conifer shelter	increases amount of interface and quality of food and shelter	1,14

[a]: Numbers correspond to numbered references as follows: 1-McCaffery and Creed (1969); 2-Nixon et al. (1970); 3-Kohn and Mooty (1971); 4-Byelich et al. (1972); 5-McCaffery et al. (1974); 6-Drolet (1976); 7-Kearney and Gilbert (1976); 8-Stocker and Gilbert (1977); 9-Euler (1979); 10-Drolet (1978); 11-Whelan et al. (1979); 12-Bennett et al. (1980); 13-OMNR (1984a); 14-McCaffery et al. (1981); 15-Tomm et al. (1981); 16-Sweeney et al. (1984).

2.2.4 Habitat Evaluation Procedures

In 1977 the United States Fish and Wildlife Service (USFWS) held a symposium on evaluation of fish and wildlife habitat to encourage investigators to coordinate and standardize development of habitat evaluation procedures (Whelan et al., 1979). In this spirit, Ellis et al. (1979) and Whelan et al. (1979) compared the accuracy and efficiency of six evaluation systems:

(1) USFWS Habitat Evaluation Procedures (HEP) Form 3-1101 (see Gysel and Lyon, 1980:324);
(2) A Handbook for Habitat Evaluation Procedures (Flood et al., 1977);
(3) Line Chart (Whitaker et al., 1976);
(4) Matrix Method (unpublished, see Ellis et al., 1978);
(5) Dynamically Analytic Silvicultural Technique (DYNAST) (Boyce, 1977, 1978), and;
(6) Information System for Wildlife Habitat Evaluation (Williamson et al., 1978).

While a discussion of the relative accuracies of these systems is not appropriate here, it is important to know their existence and the need to standardize evaluation techniques as much as possible. Whelan et al. (1979:400) pointed out "the system which incorporates the best available data and is least subjective ... should be the most accurate. ... Whenever possible, algorithms should be developed using bioenergetic information for the construction of species production functions which will best reflect the functional significance of habitat factors to species".

Gysel and Lyon (1980) reviewed the literature on evaluation procedures and vegetation sampling. Asherin et al. (1979) assessed wildlife habitat suitability for land use management purposes by measuring the diversity of bird species using the Shannon-Weaver Index (Shannon and Weaver, 1963). Habitat evaluation techniques using ordination were tested for white-tailed deer by Ellis et al. (1979) and Whelan et al. (1979). Bramble and Byrnes (1979) recommended a four-page field form that ranks habitat according to requirements of the wildlife species and a weighted average of quantitative habitat characteristics derived by ocular estimate.

Recent evaluations of white-tailed deer habitat have either stressed measurement of food resources (Short, 1986; Ormsby and Lunetta, 1987), or a holistic approach incorporating factors like deer behaviour and physiology, forage quality, weather, snowcover, topography and shelter (Robbins, 1973; Towry, 1975; Wetzel et al., 1975; Potvin and Huot, 1983). Stocker et al. (1977) and Stocker and Gilbert (1977) classified habitat by hierarchical clustering of vegetation data, and compared habitat characteristics to deer requirements with compatibility matrices.

3.0 THE STUDY AREA

3.1 Location and Physiography

The study area is OMNR Wildlife Management Unit 10 (3,500 sq.km) located between Fort Frances and Lake of the Woods in northwestern Ontario, Canada (Figure 1). It extends from the United States border north to the Strachan Road. Elevation varies from 326 to 431 m above sea level, with maximum elevation occurring in Potts township. Topography varies from gently undulating plain in the south, to moderately rolling and rocky relief in the northeast.

Northern and northeastern portions of the study area have mixed forests on rolling uplands of glacial till interspersed with peat bogs. Southern and southeastern portions are primarily agricultural areas on lacustrine deposits of the Rainy River floodplain.

Western and northern portions of the study area drain west and north into Lake of the Woods. Central and southern portions drain south into Rainy River; eastern portions flow east into Rainy Lake. Rainy Lake flows south into Rainy River which flows west into Lake of the Woods. All drainage flows from there to Hudson Bay via the Winnipeg River and Lake Winnipeg.

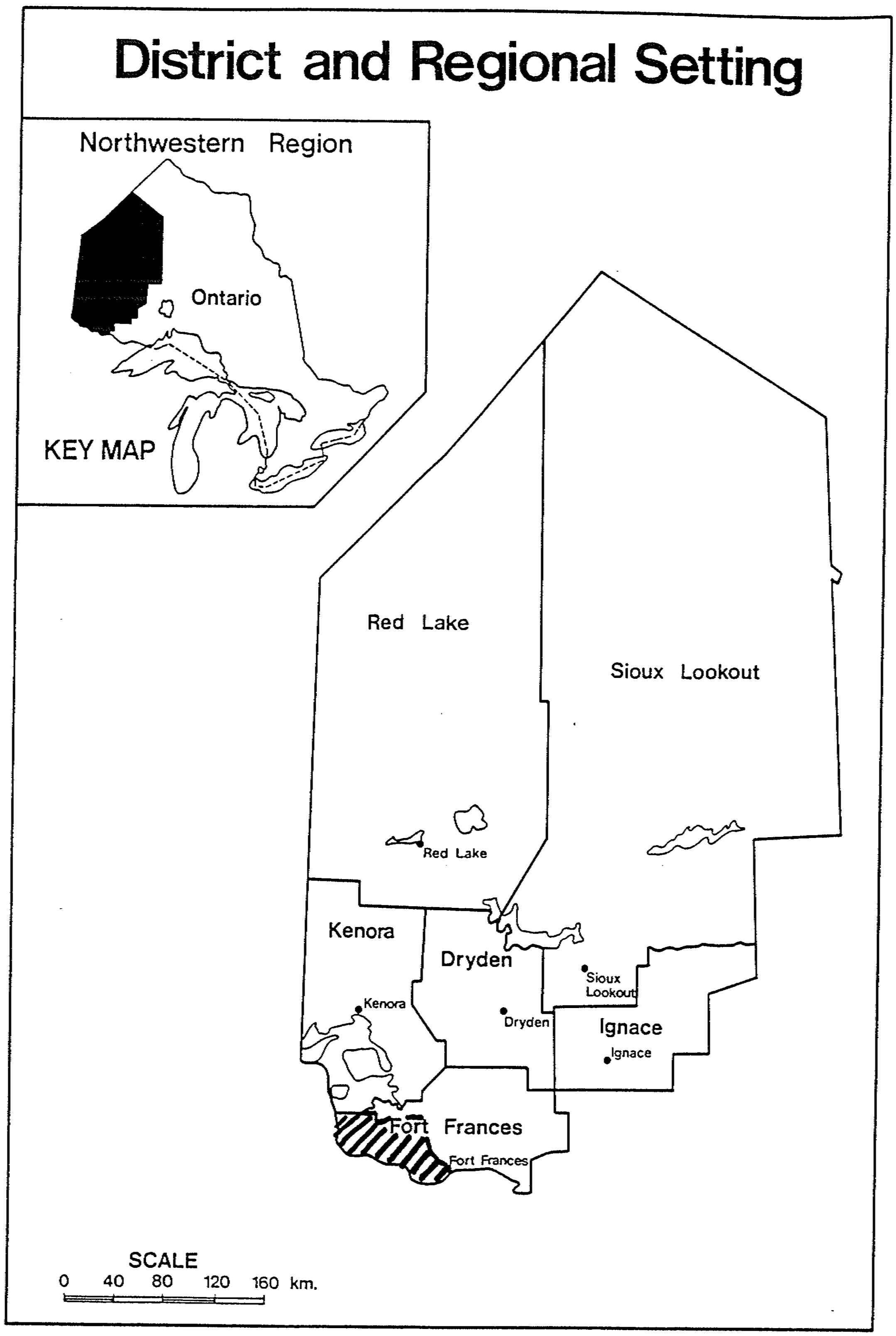

Fig. 1: The study area.

3.2 Geology and Soils

Bedrock is Precambrian Shield consisting of two main groups of crystalline rocks, both of Archaen age (Hallett and Roed, 1980). Throughout the southern half of the study area metamophosed basaltic and andesitic massive lavas lie beneath Quaternary deposits. "Metasediments and granitic plutons also occur here. The northern portion is dominated by a younger group of rocks, composed of granite and granitic gneiss in batholiths and isolated plutons" (Hallett and Roed, 1980:2).

Surficial deposits are the result of glacial retreat and inundation by glacial Lake Agassiz. They consist of glaciolacustrine clay and silt in the south and northwest, clayey silt in central portions of the study area, and silty to sandy till in the northeast (OMNR, 1976; Hallet and Roed, 1980). Till deposits are thickest in the southwest (10 to 20 metres), thinning out to exposed bedrock to the northeast (Hallett and Roed, 1980; OMNR, 1980). The most recent surficial deposits are organic soils in poorly drained depressions, and alluvium along river valleys (OMNR, 1983).

Soils of the Rainy River lacustrine plain are clay-loams that are low in acidity and are part of the Grey-Wooded Great Soil Group (OMNR, 1976). Podzolization is poorly defined, but gleization is usually evident. Impervious subsoils and poor drainage are characteristic. In northern and northeastern parts of the unit, shallow podzols have developed over silty and sandy tills (OMNR, 1976, 1980). Several large peat bogs extend east-west through the longitudinal center of the study area. For further information and maps of bedrock geology and soils of the study area refer to Hallett and Roed (1980) and OMNR (1980).

3.3 Climate

Mean daily temperatures for the study area are 19.2 degrees C for July and -16.9 for January. The frost-free period is approximately 119 days. The average date of last frost is May 23rd and first frost is September 20th. Average annual precipitation is 696 mm of which 21% falls as snow between 16 November and 10 April. Average annual snowfall is 149 cm (Environment Canada, 1982). Mean maximum snow depth is approximately 60 cm in late February. On average, freeze-over occurs on 20 November for lakes and 1 December for rivers. Break-up occurs on 7 April for rivers and 1 May for lakes (Fisheries and Environment Canada, 1978).

3.4 Vegetation

The study area lies wholly within the western end of a long finger of Great Lakes-St. Lawrence forest extending west from Lake Superior, south of the expansive boreal coniferous forest of northwestern Ontario (Rowe, 1972). It is characterized by agricultural lands scattered amongst deciduous and mixed forests. Throughout the text, vascular plant nomenclature will follow Fernald (1970).

In northern and northeastern portions of the study area, the forest is primarily mixed stands of trembling aspen (Populus tremuloides Michx.), balsam poplar (Populus balsamifera L.), balsam fir (Abies balsamea (L.) Mill.), black spruce (Picea mariana (Mill.) BSP.), white spruce (Picea glauca (Moench) Voss) and jack pine (Pinus Banksiana Lamb.). As one proceeds from northeast to southwest, these mixed stands on slightly rolling relief give way to extensive muskegs of black spruce and larch (or tamarack, Larix laricina (Du Roi) K. Koch) located east-west across central portions of the study area. Southwest of this the forest is progressively dominated by trembling aspen and balsam fir, with increasing prevalence of bur oak (Quercus macrocarpa Michx.). Eastern white cedar (Thuja occidentalis L.) is common throughout the study area, especially along margins of drainage systems and muskegs. A small amount of land clearing for agriculture and logging occurs each year, but much of the previously cleared land is allowed to regenerate into early successional forest.

The study area belongs to the Rainy River Section of the Great Lakes-St. Lawrence Forest Region as described by Rowe (1972:111):

> "The red and eastern white pines [*Pinus resinosa* Ait. and *P. strobus* L., respectively], formerly of greater extent, have now only a scattered representation on suitable sites, ... for logging and fires have led to their almost complete replacement by jackpine. Low relief and poor drainage have favoured the development of extensive swamps, with black spruce, tamarack, eastern white cedar, willow [*Salix* spp.] and alder scrub [*Alnus* spp.] ... . Large areas of balsam poplar, white spruce, balsam fir and scattered tamarack are found inland from the rivers. On the river banks white elm [*Ulmus americana* L.], Manitoba maple [*Acer negundo* L.], and bur oak occur, the latter species often forming a savanna type with grassy openings. Trembling aspen is common throughout the Section. ... However, agricultural settlement ... along Rainy River has led to considerable clearing in that area."

4.0 METHODS

4.1 Thematic Map Production

A thematic map of deer habitat derived from Landsat MSS imagery, and its complimentary computer files of classification and spectral data, were used as a data base for predicting deer habitat suitability ranks. Development of a thematic map required two attempts at production to achieve 75% minimum overall accuracy. MSS data were analyzed with a supervised classification procedure during both attempts (Alfoldii, 1978). Pixel size before geometric rectification was 56 x 79 m (Jensen, 1986). Each pixel on the map was classified to one theme by colour code.

Firstly, a 'single-date' thematic map was developed with Landsat 3 imagery taken on June 25, 1980. Sites of known vegetational composition called 'training areas' and aerial photographs were used to program the computer to recognize 13 biophysical themes relevant to the evaluation of white-tailed deer habitat (Table 6). The single-date map failed to acheive sufficient accuracy for study purposes.

Table 6: Biophysical themes of the 'single-date' thematic map and their quantitative descriptions.

Theme	Characteristic[a]	Minimum[b]	Maximum
Water	shallow & deep (% coverage)	50	100
Marsh	density of trees (#/ha)	0	0
Fen with Surface Water	density of trees (#/ha)	0	0
	% covered by water	10	80
Open Bog	density of trees (#/ha)	0	50
	dominant tree species	Sb/L/Ab	N/A
Treed Bog	density of trees (#/ha)	51	N/A
	dominant tree species	Sb/L/Ce	N/A
	% conifer in stand	75	100
	height of swd trees (m)	2	N/A
Sand, Open Soil & Rock Outcrop	density of trees (#/ha)	0	5
	dominant tree species	Pj	N/A
Hardwood Forest	density of trees (#/ha)	25	N/A
	dominant tree species	Po	N/A
	% conifer in stand	0	25
	height of hwd trees (m)	14	N/A
Softwood Forest	density of trees (#/ha)	25	N/A
	dominant tree species	Pj/Sw/Pr	N/A
	% conifer in stand	75	100
	height of swd trees (m)	2	N/A
Mixed Forest	density of trees (#/ha)	25	N/A
	dominant tree species	Po/B	N/A
	% conifer in stand	26	74
Unimproved Pasture	density of trees (#/ha)	0	24
	density of shrubs (#/ha)	0	20
	evidence of cultivation	absent	N/A
Developed Agricultural Land	density of trees (#/ha)	0	24
	density of shrubs (#/ha)	0	20
	evidence of cultivation	present	N/A

. . . continued

Table 6 continued . . .

Shrubs & Early Successional Forest	density of trees (#/ha)	21	N/A
	dominant tree species	Al/Po/Sw	N/A
	height of trees (m)	0	13
	age of trees (yr)	1	30
	% conifer in stand	N/A	74
Urban Area	manually designated in program	N/A	N/A

a : If height of swd trees was less than 2 m, the stand was classified as open wetland, or shrubs & early successional forest.

b : Units for minimum and maximum are shown under characteristic. Tree species codes used are as follows: Sb = black spruce [*Picea mariana* (Mill.) BSP.]; L = larch [*Larix laricina* (Du Roi) K. Koch]; Ab = black ash (*Fraxinus nigra* Marsh.); Ce = cedar (*Thuja occidentalis* L.); Pj =jackpine (*Pinus Banksiana* Lamb.); Sw = white spruce [*Picea glauca* (Moench) Voss]; Pr = red pine (*Pinus resinosa* Ait.; Po = poplar, either trembling aspen (*Populus tremuloides* Michx) or balsam poplar (*P. balsamifera* L.); Al = alder, either speckled alder [*Alnus rugosa* (Du Roi)Spreng.] or mountain alder [*A. crispa* (Ait.) Pursh]. Evidence of cultivation means as observed on aerial photographs.

Secondly, multi-date imagery was employed to improve differentiation of themes by examining vegetation at different stages of phenology. MSS data taken from Landsat 3 on June 25, 1980 and from Landsat 4 on May 8, 1983, were used to develop a 'multi-date' map that recognized 10 biophysical themes (Table 7), consolidated from the 13 single-date themes (Table 6). New or refined training areas, and airphotos, were used for programming.

Use of a third winter image during production of the multi-date map was attempted but rejected. Although it improved differentiation of coniferous and mature deciduous forest, it greatly confused classification of other habitat types.

In each case, single and multi-date, a supervised classification of MSS data was conducted on a DIPIX ARIES II digital image analysis system at the Ontario Centre for Remote Sensing (OCRS), 90 Sheppard Ave. E., North York, Ontario M2N 3A1. During production of the multi-date map, this system comprised one PDP 11/34 computer and two separate sets of image display hardware: a NORPAK 3050 Image Display System and a DIPIX LCT-11 (Pala and Jano, 1981). Software for the system was based on the ARIES (Applied Resource Image Exploitation System) image processing software.

Table 7: Biophysical themes of the 'multi-date' thematic map and their quantitative descriptions.

Theme	Characteristic[a]	Minimum[b]	Maximum
Water	shallow & deep (% coverage)	50	100
Open Wetlands	density of trees (#/ha)	0	50
	dominant tree species	Sb/L/Ab	N/A
Lowland Conifer Forest	density of trees (#/ha)	51	N/A
	dominant tree species	Sb/L/Ce	N/A
	% conifer in stand	75	100
	height of swd trees (m)	2	N/A
Upland Conifer Forest	density of trees (#/ha)	25	N/A
	dominant tree species	Pj/Sw/Pr	N/A
	% conifer in stand	75	100
	height of swd trees (m)	2	N/A
Deciduous Forest	density of trees (#/ha)	25	N/A
	dominant tree species	Po	N/A
	% conifer in stand	0	25
	height of hwd trees (m)	14	N/A
Mixed Forest	density of trees (#/ha)	25	N/A
	dominant tree species	Po	N/A
	% conifer in stand	26	74
Unimproved Pasture	density of trees (#/ha)	0	24
	density of shrubs (#/ha)	0	10
	evidence of cultivation	absent	N/A
Developed Agricultural Land	density of trees (#/ha)	0	24
	density of shrubs (#/ha)	0	10
	evidence of cultivation	present	N/A
Shrubs & Early Successional Forest	density of shrubs (#/ha)	11	N/A
	dominant tree species	Al/Po/Sw	N/A
	height of hwd trees (m)	0	13
	age of trees (yr)	1	30
	% conifer in stand	N/A	74
Urban Area	manually designated in program	N/A	N/A

. . . continued

Table 7 continued . . .

[a] : If height of swd trees was less than 2 m, the stand was classified as open wetland, or shrubs & early successional forest.

[b] : Units for minimum and maximum are shown under characteristic. Tree species codes used are as follows: Sb = black spruce [*Picea mariana* (Mill.) BSP.]; L = larch [*Larix laricina* (Du Roi) K. Koch]; Ab = black ash (*Fraxinus nigra* Marsh.); Ce = cedar (*Thuja occidentalis* L.); Pj = jack pine (*Pinus Banksiana* Lamb.); Sw = white spruce [*Picea glauca* (Moench) Voss]; Pr = red pine (*Pinus resinosa* Ait.; Po = poplar, either trembling aspen (*Populus tremuloides* Michx) or balsam poplar (*P. balsamifera* L.); Al = alder, either speckled alder [*Alnus rugosa* (Du Roi) Spreng.] or mountain alder [*A. crispa* (Ait.) Pursh]. Evidence of cultivation means as observed on aerial photographs.

Image analysis was performed by OCRS staff with my assistance, since I was familiar with the study area and had examined selected training areas on the ground and from the air. The sequence of steps performed during both supervised classifications is outlined below.

The image was first geometrically rectified to the Universal Transverse Mercator (UTM) grid system with a first order transformation, namely adjusting scale, rotating the image and shifting origin to align the image with ground control points. Intensity interpolation (Jensen, 1986) of the imagery was then necessary. This involved resampling the image data using a cubic convolution algorithm to produce an output image having a pixel size of 40m x 40m (Jensen, 1986) to facilitate plotting on the APPLICON printer. It is the 40m x 40m plotted pixels that are referenced on the thematic maps and in subsequent sections of the text.

Prior to classification, potential training areas were chosen at a number of sites scattered across the study area, from airphotos and 1:50,000 scale topographic maps. These were subjectively screened for biophysical characteristics and species. Training areas for complex themes were observed by aircraft overflight and ground inspection.

Training areas for the single-date map were not selected to represent 'pure' examples of a theme. Instead, an assumption was made they should be selected on the basis of being 'typical' and should include some variablility of type. For example, the single-date training areas for unimproved pasture included some shrubs because a low density of shrubs was often observed in unimproved pastures of the study area. Later, this assumption proved to be erroneous. The inclusion of some variability of type proved to confuse classification and reduce map accuracy.

Multi-date training areas were therefore selected to represent 'pure' examples of a theme. For example, shrubs were excluded from the training areas for unimproved pasture. Methods of choosing, verifying, refining and recording multi-date training areas were the same as those for single-date programming with the exception that 10 revised themes were employed (Table 7). Analyst familiarity with the study area, and field inspection of the training areas was essential to achieving acceptable accuracy.

Image analysis commenced with an examination of the MSS image in false colour on an image display terminal. Fields and forest openings were readily identifiable and image quality was good. Using this image, and a raw infrared image, it was obvious that subdivision of some themes was necessary to avoid bimodal frequency distributions of spectral data and allow separation of spectrally dissimilar types (eg. deep water vs. shallow water, marsh vs. fen, various agricultural crops). This necessitated selection of some new training areas for theme subdivisions.

Subsequently, training areas were located and delineated on the false colour image using the computer and saved for spectral analysis. In many cases, final boundaries of the training areas were located inside the preliminary boundaries to avoid including pixels that subjectively appeared to have 'mixed' spectral characteristics judging from the false colour image. Spectral signatures of the training areas were then generated. The 'urban area' theme was manually delineated.

It is a normal procedure at OCRS to perform an 'autocorrelation distance analysis' on spectral signatures of the training areas, although this was not done for the single-date map. This program generates a matrix of index values that represents the relative closeness of spectral signatures in n-dimensional feature space. Large index values indicate good separation of training area signatures, values less than one indicate large overlap, and zero indicates identical signatures. Themes with serious overlap problems necessitate examination of frequency histograms, means and covariances of spectral bands; training areas are then deleted, modified or added as necessary to obtain acceptable signature separation. In the case of the multi-date map, 22 training area spectral signatures were required to classify 10 themes.

A maximum likelihood program was used to do the supervised classification. This program used the spectral signatures of training themes and sub-themes to estimate the probabilities of pixel membership in each theme or sub-theme of the classified image. In other words, pixels were assigned to the theme or sub-theme that maximized the likelihood of a correct classification, given information in the training data (Campbell, 1987). Computation of the estimated likelihoods was based on the assumption that both training data and the classes themselves displayed multivariate normal frequency distributions; hence the need for unimodal distributions (Campbell, 1987).

After classification, sub-divided themes were merged to represent the themes listed in Tables 6 and 7 before the thematic maps were plotted. Output from the supervised classification was: a colour thematic map of 1:50,000 scale geometrically corrected to the UTM grid and printed by an APPLICON plotter (Pala and Jano, 1981); a computer-compatible tape (CCT) of classification data (frequency of themes for each sq.km); a CCT of spectral signature files for the training areas (means, covariances and inverses); hardcopy summary printouts of classification data for 10km x 10km UTM grid cells and spectral signature files for the training areas (Appendix 1).

4.2 Map Accuracy Assessment

Accuracy of the single and multi-date maps was assessed by comparing map theme for a stratified random cluster sample of pixels, to true theme as determined by airphoto interpretation, and in difficult cases, by ground or aerial observation. A sample unit of nine contiguous pixels (3x3) of homogeneous theme was used (Todd et al., 1980). A single pixel unit was not used due to potential errors of $\pm$ one pixel in aligning imagery, airphotos and ground sample sites, or resulting from intensity interpolation and geometric rectification of the image. Samples were stratified by theme, with 50 samples being drawn randomly per theme for each map assessment (Hay, 1979). Sampling occurred over the entire map, rejecting assignments to strata once their requirement was filled, until all strata had 50 samples drawn.

Cluster sampling was used to overcome logistic problems in drawing random samples from such large complex maps; each map contained 2,259,180 classified pixels. It was also used to avoid complex computer sampling of sparse themes (Fitzpatrick-Lins, 1981). Square kilometer (UTM) grid cells of the classified portion of a map were numbered sequentially, and a table of random numbers (Steel and Torrie, 1960) was used to draw sq.km samples. Each sq.km selected was cluster sampled (systematically sub-sampled) to obtain pixels for accuracy assessment. This was accomplished by repeatedly using an acetate overlay on which a square grid of 10x10 cells had been drawn at 1:50,000 scale, each cell representing one sq.km. The central cell contained seven random cut-outs of 3x3 pixels each. By placing the acetate overlay on the thematic map over the sq.km to be sampled, and orienting according to the UTM grid, it was possible to sample 3x3 pixel units. A corresponding acetate overlay of 1:15,840 scale was used to sample aerial photographs (1:15,840 scale), orienting by UTM grid lines drawn on the photos. A sample unit was included as one of 50 required samples for a theme if all nine contiguous pixels belonged to that theme. If not, another random sample site was examined.

Classification accuracy, for each 3x3 pixel sample, was determined by interpretation of summer 1982 airphotos, referring to 1983 OMNR Forest Resource Inventory (FRI) Maps (1:15,840 scale), and by doing ground or aerial inspections when interpretation was difficult. Criteria used for differentiating themes were the same as those used during supervised classification of the maps (Tables 6 and 7). Assessment results were tabulated in contingency tables with columns representing map category (j) and rows representing true category (i). Individual cell entires of the matrix were referred to as 'nij'.

Overall map accuracy ($\hat{P}c$) was corrected for differential sampling rate bias between rare and common themes using the methods of Card (1982), where:

$$\hat{P}_c = \sum_{j=1}^{r} \pi_j \, n_{jj} / n_{.j}$$

= the sum of proportions of sampled pixels correctly identified for each theme ($n_{jj}/n_{.j}$) weighted by π_j, where:

$$\pi_j = N_{.j} / N;$$

= the proportion of classified pixels in map category j for the entire study area.

In other words, because each theme was sampled equally (n=50) during accuracy assessment, rare themes could contribute disproportionately to the estimate of average accuracy. For example, a rare theme having very poor accuracy would contribute to the estimate of average map accuracy with an influence equal to that of a very common, accurate theme. This bias was corrected by area-weighting the proportion correct for a given theme, $n_{jj}/n_{.j}$, by π_j, the number of classified pixels in that theme divided by the total number of classified pixels on the map. This yielded the unbiased proportion correct, P_{jj}.

Thus, $\hat{P}_{jj} = \pi_j \, n_{jj} / n_{.j}$, and $\hat{P}_c = \sum_{j=1}^{r} P_{jj}$.

Average unbiased percentage accuracy with 95% confidence limits (Card,1982) was first calculated for the single-date map. The results did not achieve the minimum acceptable accuracy of 75% (see Sec. 5.1). Hence, the multi-date map was produced and assessed for accuracy using similar methods. Accuracy assessment of the multi-date map showed that unimproved pasture and developed agricultural themes had to be combined to achieve 75% overall unbiased accuracy. This was done, as well as combining lowland conifer and upland conifer into one theme. The resultant map shall be referred to hereafter as the 'modified multi-date map'.

Only one procedure was used to reduce errors associated with temporal habitat changes in the field, otherwise such errors were assimilated in the accuracy assessment results. This procedure was an editing routine performed on the multi-date map to correct known errors or artifacts. The single-date map was not subjected to an editing routine.

4.3 Predicting Habitat Suitability Ranks

Habitat of a given area can be expected to differ in suitability for white-tailed deer on the basis of three factors: (1) season; (2) the presence and spatial distribution of desirable habitat types, and; (3) the abundance, diversity and suitability of food, cover and site characteristics. Habitat of the study area was evaluated for summer, winter and year-round suitability, for each sq.km of the study area. A sq.km cell was chosen for logistical convenience and because average seasonal home range size of northern white-tailed deer varies from 43 to 950 ha with deer sometimes moving up to 40 km between summer and winter range (Shaw and Ripley, 1965; Rongstad and Tester, 1969; Kohn and Mooty, 1971; Drolet, 1976; Nelson and Mech, 1981; Tierson et al., 1985; Mooty et al., 1987). The evaluation of habitat suitability for each sq.km cell was done in isolation from factors present in adjacent cells. While this does not reflect reality, it was necessary to develop a practical evaluation technique that was compatible with deer home range size and the marked patchiness of habitat in the study area.

A predicted habitat suitability rank from 1 to 5 was generated for each sq.km classified on the modified multi-date map, with 1 representing optimal white-tailed deer habitat and 5 representing unsatisfactory habitat. A matrix of predicted ranks was produced for each of the summer, winter and year-round evaluations. These ranks were derived by a computer program written using SAS (SAS Institute Inc., 1985a) that compared MSS thematic data for two variables to a set of optimal standards for white-tailed deer on northern range derived from the scientific literature. The variables employed were:

CATPROP - the proportion of each sq.km classified to a given category (theme). There was a separate CATPROP variable for each theme (eg. CATPROP1, CATPROP2, CATPROP3 etc., shortened to the acronyms CP1, CP2, CP3 etc. for simplicity);

EI - edge index determined for each sq.km. This was a manual count of theme intersects along two diagonal lines drawn on each sq.km UTM cell of the modified multi-date map according to the methods of Brooks and Scott (1983).

For a given sq.km, the computer predicted a rank from 1 to 5 for each CATPROP variable for each seasonal period depending on the amount of deviation from the optimal value or range for that variable during that season (Table 8). Optimal values or ranges were refined from Tables 3 and 4. Urban areas were assumed to have limited value for deer, so optimum proportion in the urban theme was assumed to be zero. CATPROP variables in Table 8 correspond to habitat themes of the modified multi-date map.

The predicted rank for the appropriate season increased from 1 to 5 as deviation increased in equal increments from the optimal value or range. The decision to increase predicted rank based on equal increments of deviation was an arbitrary one made during programming. The increase in predicted rank was calculated by SAS statements similar to the generic one given below:

```
IF OPTLOX LE CPX LE OPTUPX THEN RANKX = 1;
IF CPX LT OPTLOX THEN RANKX = 1+INT(0.99+(OPTLOX-CPX)/(OPTLOX/4));
IF CPX GT OPTUPX THEN RANKX =
1+INT(0.99+(CPX-OPTUPX)/((100-OPTUPX)/4));
```

```
Where:        X = category (theme) number;
            CPX = CATPROP1, CATPROP2, CATPROP3 etc.;
         OPTLOX = lower optimum limit of x;
         OPTUPX = upper optimum limit of x;
          RANKX = predicted rank for theme x;
             LE = less than or equal to;
             LT = less than;
             GT = greater than, and;
            INT = integer.
```

Table 8: Seasonal optimal values of CATPROP variables used to predict habitat suitability ranks for white-tailed deer.

CATPROP Variable	Habitat Theme	Optimal Value or Range[a]			Citation[b]
		Summer	Winter	Yr-Round	
CP1	water	0-15	0-15	0-15	16,18,24
CP2	open wetlands	0-15	0-15	0-15	6,16
CP34	coniferous forest	0-15	10-60	10-30	1,2,5,8,11,13, 14,15,16,17,18, 19,20,21,24,25, 26
CP5	deciduous forest	5-15	0-15	5-15	3,9,12,13,16,22
CP6	mixed forest	10-30	10-60	10-30	6,12,13,16,24, 27
CP78	unimproved pasture & developed agricultural	3-20	3-20	3-20	3,4,6,7,9,13, 16,17,21,22
CP9	shrubs & early successional forest	15-55	15-55	15-55	3,4,5,6,7,8,10, 11,12,13,15,16, 17,21,22,23,24
CP10	urban	0	0	0	

[a]: % of total area.

[b]: numbers correspond to numbered references as follows: 1-Davenport et al. (1953); 2-Gill (1957a in Hall 1984); 3- McCaffery and Creed (1969); 4-Nixon et al. (1970); 5-Telfer (1970); 6-Kohn and Mooty (1971); 7-Byelich et al. (1972); 8-Huot (1974); 9-McCaffery et al. (1979); 10-Telfer (1974 in Hall 1984); 11-Wetzel et al. (1975); 12-Drolet (1976); 13-Kearney and Gilbert (1976); 14-Moore and Boer (1977 in Hall 1984); 15-Smith and Borczon (1977); 16-Stocker and Gilbert (1977); 17-Euler (1979); 18-Whelan et al. (1979); 19-Euler and Thurston (1980); 20-Gates and Harman (1980); 21-OMNR (1984a); 22-McCaffery et al. (1981); 23-Tomm et al. (1981); 24-Armstrong et al. (1983a); 25-Smith and Verkruysse (1983); 26-Weber et al. (1983); 27-Mooty et al. (1987)

RANKX's for a given season for the sq.km were arithmetically averaged, after which the program proceeded to evaluate EI for the sq.km.

My review of the scientific literature failed to find any quantitative description of optimal edge for white-tailed deer habitat. Determination of an optimal range of EI based on experimental technique was beyond the scope of this study. However, empirical data were available from the MSS thematic map as well as from airphotos.

The range of EI counts for square kilometers of the study area from the modified multi-date map was 0 to 40. The sq.km with 40 intersects (UE9314) contained five themes with contiguous theme segments varying in size from one pixel (1600 sq.m) to an irregular segment of 81 pixels (129,600 sq. m). Subjectively, this was not considered to be excessively heterogeneous for white-tailed deer. Hence it was decided to divide the frequency distribution of EI counts into quantiles using a SAS univariate analysis. EI was assigned a rank of 1 for counts from 0 to quantile 1 (Q1 = 0 to 12 intersects, or the lower 25% of the frequency distribution), a rank of 0 for counts from Q1 to Q3 (13 to 20, or 26% to 75%), and a rank of -1 for counts in the top quantile Q3 to Q4 (21 to 40, or 75% to 100%). This had the effect of improving predicted habitat rank for a square kilometer by one integer if EI was in the top quantile for the study area, or worsening it by one if EI count was in the bottom quantile . The SAS statements used were:

```
IF EI LE 12 THEN RANKEI = 1;
IF 12 LT EI LT 21 THEN RANKEI = 0;
IF EI GE 21 THEN RANKEI = -1.
```

The predictive computer program then added RANKEI to the average of RANKX rounded to the next highest integer to obtain the habitat suitability rank for the sq.km, called RANK. The generic SAS statements used were:

```
RANK = INT(0.99+(RANK1 + RANK2 + RANK34 + ... RANK10)/10) + RANKEI;
IF RANK EQ 0 THEN RANK = 1;
IF RANK EQ 6 THEN RANK = 5.
```

The SAS computer program for generating a matrix of predicted habitat suitability ranks for the year-round period is given in Appendix 2 as an example of this technique.

4.4 Field Sampling Procedures

4.4.1 Site and Vegetation Sampling

Ground sampling of trees, cover, forage, site fertility, slope, aspect, presence or absence of water, browse and herbaceous deer foods was conducted on a simple random sample of sq.km UTM cells (n=66) in the study area (Figure 2). Field sampling was performed during the summers of 1984, 1985 and 1986. The information derived was used in Test 1 and Test 2 (see Secs. 4.5.1 and 4.5.2).

A total of 40 random plots were sampled on 4 random transects at each sample cell. Transects were randomly oriented east-west or north-south, and 10 plot locations were randomly spaced along each transect. A two-person field crew walked a transect by orienting with compass and OMNR Forest Resource Inventory (FRI) map, measuring distance by dragging a 40 m rope and marking their route with flagging tape. At each plot location three sampling procedures were followed (see also Appendices 3 and 4):

(1) Two-Factor Prism Plot: A count was made by species of all trees falling within the prism plot, for determination of stand composition, stocking density and basal area (sq.m/ha). Other stand parameters recorded were working group (dominant tree species), age by increment bore, height using a

clinometer (Suunto Oy, Helsinki, Finland), site fertility index (Plonski, 1974), slope in degrees using a clinometer, aspect, and percent conifer crown closure by ocular estimate.

(2) 1 x 10 m Plot: This plot was sampled at the center-point of each two-factor prism plot using the center as the right-hand starting point of the 1 x 10 m plot, the right side of which was formed by the rope lying along the transect. On each plot the field crew recorded: presence or absence of surface or permanent water that deer could drink; number of browsed and unbrowsed twigs of important browse species for white-tailed deer at five different height ranges above ground, 0-25, 26-50, 51-75, 76-200 and 0-200 cm, and; percentage herbaceous cover by ocular estimate (Appendix 4). After an initial training period, counts of browsed and unbrowsed twigs were made on a Daubenmire scale by ocular estimate.

(3) 1 x 1 m Plot: At the end of each 1 x 10 m plot, the abundance of herbaceous food plants important for white-tailed deer on a 1 x 1 m plot was recorded by species, by ocular estimate of percentage of the plot covered by that species, on a Daubenmire scale (Appendix 4).

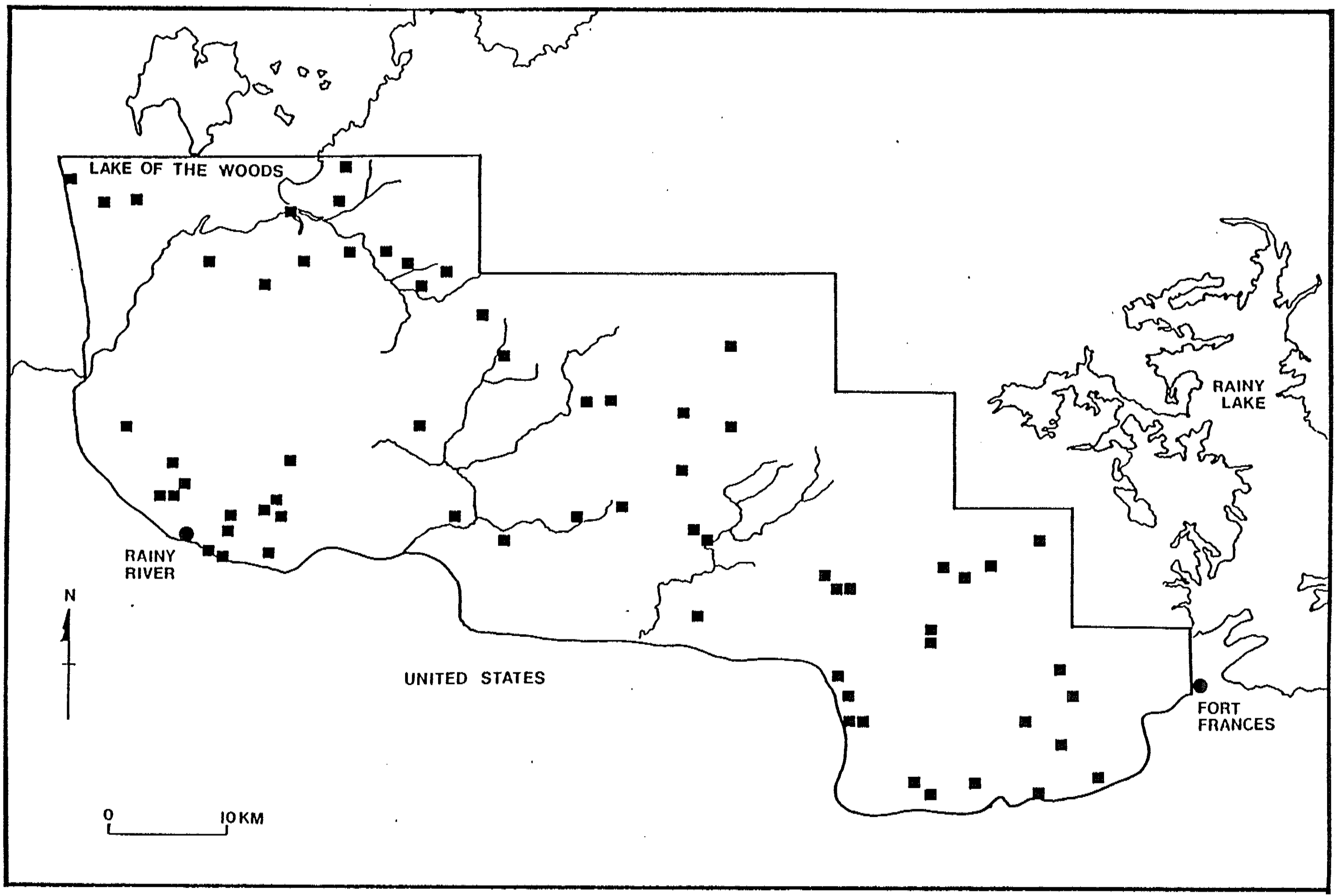

Fig.2: The location of a simple random sample of sq.km UTM cells (n=66) in the study area on which airphoto interpretation and field sampling of deer habitat was conducted for Tests 1 and 2.

4.4.2 Over-winter Deer Density Sampling

Firstly, stratification of deer distribution into high and low density and non-deer habitat was conducted in February 1982, by flying east-west transects in a Turbo-Beaver aircraft at 3.2 km intervals 140m above ground at 150 km/h (Figure 3).

Secondly, from 4 to 21 May, 1982, pellet groups were counted on 982 plots on 118 stratified random sample sites (Figure 4) following OMNR standards and guidelines for pellet group survey (OMNR, 1984a). Each sample site was an equilateral triangle, 1 km on each side, containing nine 2 m x 40 m plots around the perimeter. Twenty university and high school students were intensively trained and used in 10 teams of 2 to conduct the survey. The students followed a compass heading following the pre-planned triangular route on an FRI map, and measured distance with a 40m rope. In order to check results, the route and plots were marked with flagging tape. At each plot the rope was used as plot midline, and each student searched a strip 1 m wide on each side. Pellet groups counted on the plot were painted with flourescent red paint.

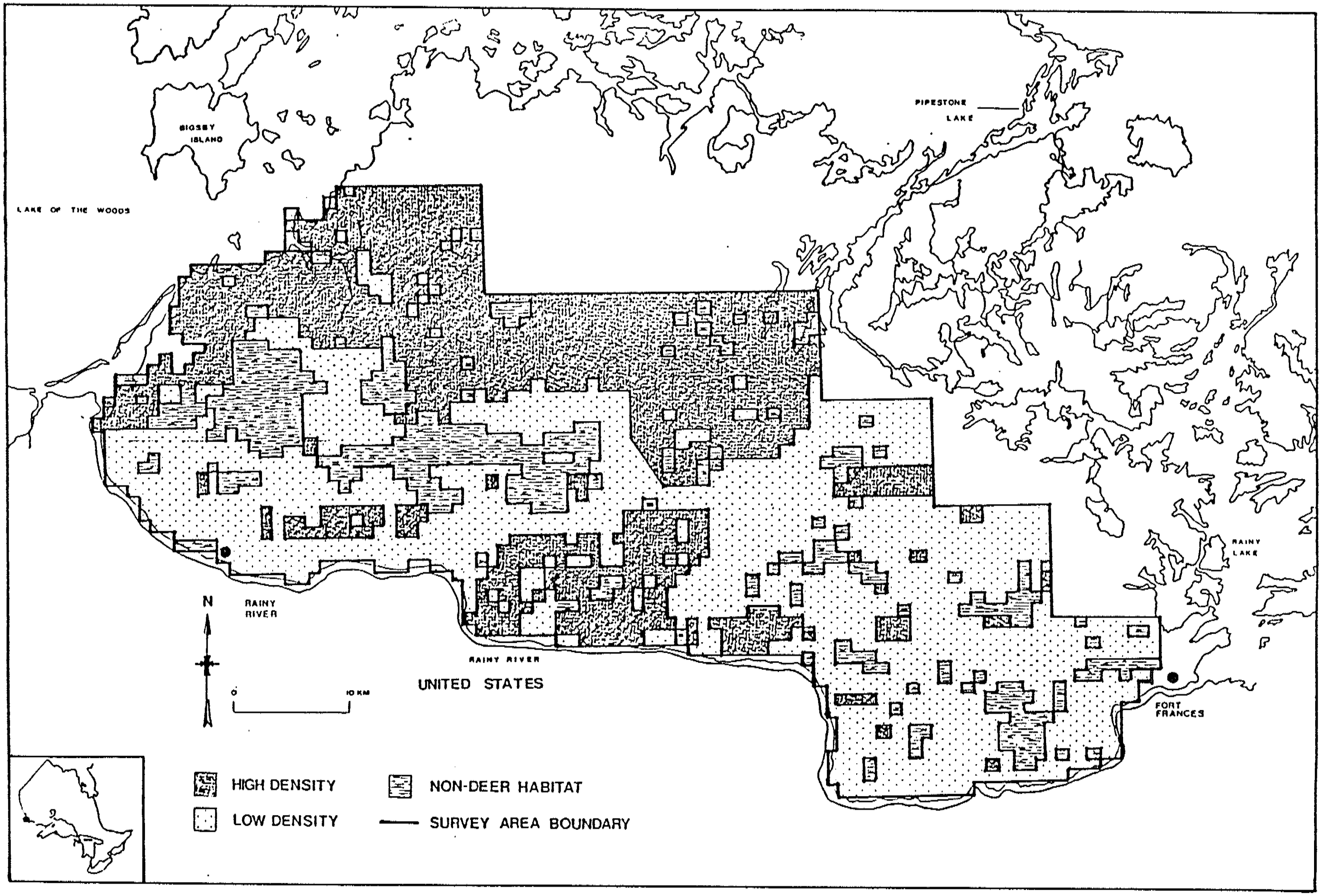

Fig. 3: Map of the February, 1982, deer distribution used as stratification for the 1982 deer pellet group survey of the study area. High density means greater than 20 track aggregates sighted per 10 km of aerial transect. Low density is 20 or fewer track aggregates per 10 km of transect.

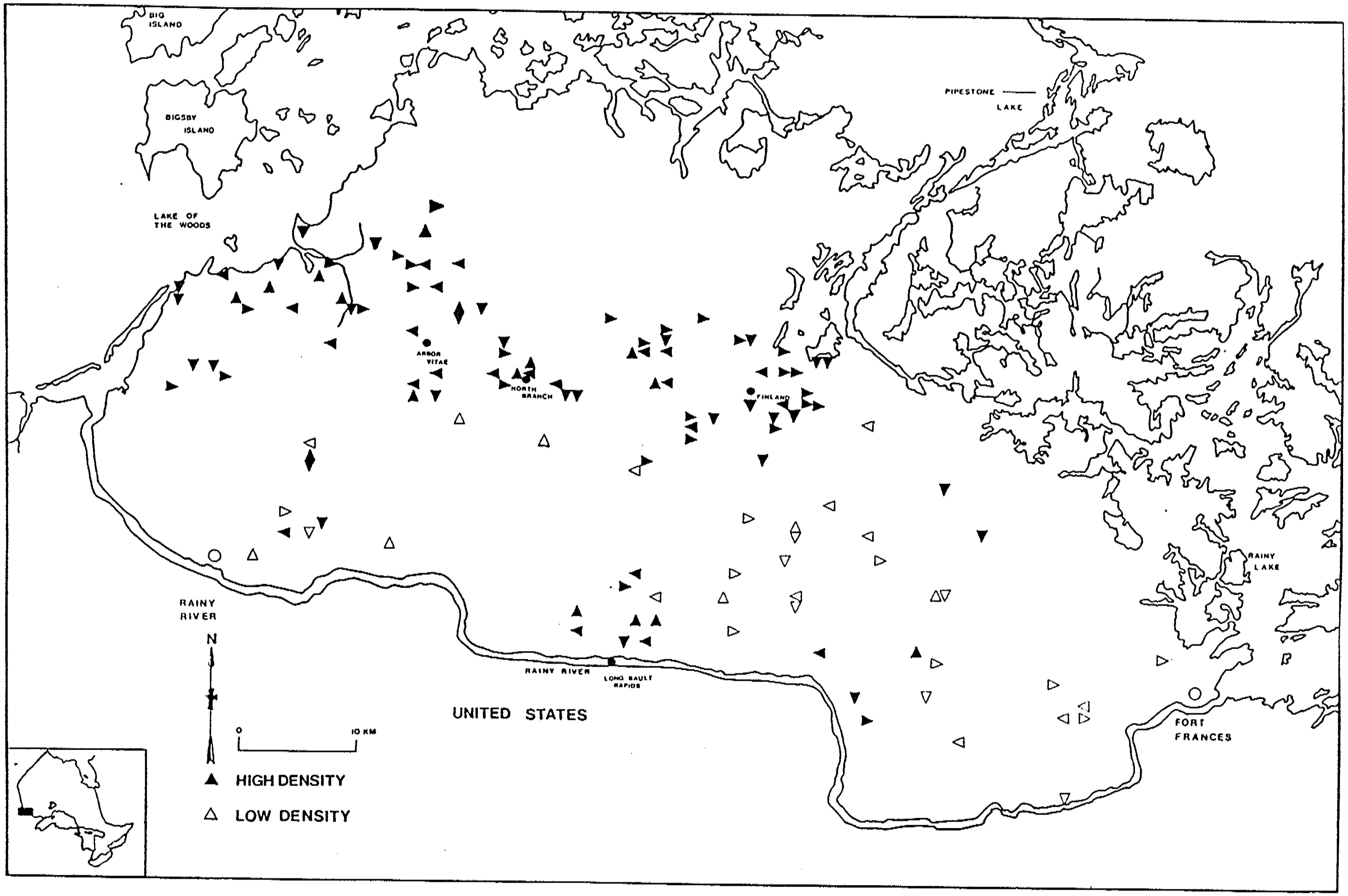

Fig.4: The location of a stratified random sample of 118 triangular routes on which deer pellet groups were counted during the 1982 pellet group survey.

Inspections for missed groups or errors on 5% of all triangles resulted in a correction factor of 1.083 being applied to stratum estimates of pellet group density. Pellet deposition period was 214 days based on a date of 90% leaf fall of October 10, 1981. A mean defecation rate of 13.8 pellet groups per day was used to calculate over-winter deer density as follows (Ryell, 1971; OMNR, 1984b):

$$\text{deer/sq.km} = \frac{\text{weighted mean pellet group density for all strata, corrected for errors, times 12,500 plots per sq.km}}{\text{deposition period times mean defecation rate}}$$

Details of the field survey methods are given by Darby and Munn (1982), and Darby (1980).

4.5 Testing Predicted Ranks

4.5.1 Test 1 - Correlation with Independently Measured Ranks

Test 1 comprised correlation of predicted year-round ranks with year-round test ranks derived from independent measurements of CATPROP and EI for a simple random sample of sq.km UTM cells in the study area (n=66). The generic SAS statements used to generate predicted year-round ranks (Sec. 4.3) were also used to generate Test 1 ranks. The independent measurements were taken from aerial photographs and ground sampling data (Sec. 4.4.1) by the following techniques:

CATPROP - the boundary of each sq.km sampled was carefully drawn on stereo pairs of 1982 aerial photographs (1:15,840 scale). Classification and mapping of habitat to theme was done by airphoto interpretation according to the criteria used during supervised classification of the multi-date map (Table 7). Exceptions were that the unimproved pasture and developed agricultural themes were pooled, and coniferous forest themes were pooled, to coincide with the modified multi-date map. Airphoto interpretation was verified by reference to 1983 OMNR FRI maps (1:15,840 scale), or by ground sampling data for the site (Sec. 4.4.1). CATPROP measurements were obtained for each theme from the interpreted airphoto using a Koizumi Placom KP-90 digital planimeter.

EI - After classification of the sq.km sample on the airphoto, a manual count of theme intersects was made along two diagonal lines drawn across the sample cell (Brooks and Scott, 1983). The count constituted the edge index.

Correlation of predicted year-round ranks with Test 1 ranks (truth) for sample cells was performed using the SAS correlation procedure (SAS Institute Inc., 1985a). Initially, the correlation was performed on integer values for both the predicted and Test 1 ranks, since the computer program predicted integer ranks for presentation simplicity (Appendix 2). It quickly became apparent, however, that any attempt to correlate integer values violates the correlation procedure assumption of a bivariate normal distribution (Steel and Torrie, 1960). In other words, the assumption of continuous variables had been violated (Snedecor and Cochran, 1967). Predicted and Test 1 ranks for the Test 1 sample were subsequently recalculated to be numbers to two decimal places (Appendices 5 and 6). The Test 1 correlation was then performed on these ranks (Appendix 6).

4.5.2 Test 2 - Correlation with Food, Cover and Site Data from Field Sampling

MSS imagery does not penetrate the forest canopy well, and thus cannot provide a direct measure of food and cover available to white-tailed deer. Test 2 was designed to test the inference that food, cover and site characteristics follow a gradient of increasing diversity, abundance and suitability from predicted low-ranking to high-ranking cells. This was done by performing a canonical correlation (SAS Institute Inc., 1985b; Appendix 7) between predicted year-round ranks and food, cover and site data acquired by ground sampling (Sec. 4.4.1). The canonical correlation was also performed between Test 1 ranks and Test 2 field data to better evaluate the results of Test 2.

Test 2 was performed on data for the same random sample of 66 UTM cells used in Test 1. Ground sampling involved measuring forest stand composition, abundance and diversity of important deer forage species, coniferous canopy cover, slope, aspect, and site fertility, on 40 random plots per sq.km sample cell; 10 on each of 4 random transects per cell (Sec 4.4.1). These data were summarized into 15 variables for the purpose of Test 2 (Table 9).

4.5.3 Test 3 - Correlation with Over-winter Deer Density Distribution

Test 3 correlated predicted winter rank with over-winter deer density determined by a 1982 pellet group survey, for a stratified random sample of sq.km UTM cells (n=112; Sec. 4.4.2). These sample cells were not the same sites used in Tests 1 and 2.

Recall that the dates of imagery used in production of the modified multi-date map were June 25, 1980 and May 8, 1983. Pellet group data obtained in spring 1982 were used to generate over-winter deer density estimates for the winter of 1981-82.

Table 9: Test 2 summary variables. See Section 4.4.1 for original variables and field sampling methods.

Variable	Description
NTHEME	The number of times the variable 'biophysical category' or 'theme' (BIOCAT, Appendix 3) changed its value throughout records for a particular UTM sample cell. For example, five themes may have been encountered at 40 plots for a given sq. km sampled, but theme may have changed 28 times.
NDOMTREE	The number of times the variable defining dominant tree species or 'working group' in a plot (WG, Appendix 3) changed its value for a particular UTM sample cell
MTBA	Mean total basal area per plot (sq.m/ha), of all tree species
MCBA	Mean basal area per plot of all coniferous trees
MSCBA	Mean basal area per plot of coniferous tree species suitable as winter cover for deer and present in the study area (white, red and jack pine, white spruce, balsam fir and cedar)
MSTDAGE	Mean forest stand age per plot
MSTDHT	Mean forest stand height per plot
MFERT	Mean soil fertility per plot
MSLOPE	Mean slope per plot
MASPECT	Mean aspect per plot
MCCC	Mean conifer canopy closure per plot
MNBSP	Mean number of deer browse species per 10 sq.m plot

. . . continued

Table 9 continued . . .

MBD	Mean deer browse density per plot (unbrowsed twigs per 10 sq.m to 200cm above ground)
MNHSP	Mean number of deer herbaceous food species per 1 sq.m plot
MHD	Mean herbaceous food density (% ground cover on 1 sq.m)

It was recognized that poor correlation may or may not imply poor predictions of habitat suitability rank. Poor correlation could, at least in part, result from other factors affecting deer distribution such as human disturbance or predators. Nonetheless, the proportion of variability explained by the correlation would be valuable information. Correlation of the two data sets was accomplished using SAS (Appendix 8).

5. RESULTS

5.1 Single-Date Imagery Production and Accuracy

The single-date map of deer habitat (Plate 1) was produced in 1982 using Landsat 3 MSS imagery from June 25, 1980. Scale of the map was 1:50,000 with 13 habitat themes represented (Table 6). Production quality of the single-date map was good in that printing quality was good, the scale was accurate and the image had only a few small clouds in the southeastern portion of the study area. However, accuracy of the themes was poor.

Unbiased overall map accuracy was 59.0 ± 4.5 % ($P<0.05$, Tables 10 and 11). Overall map accuracy ($\hat{P}c$) was obtained by summing the underlined diagonal entries in Table 11. Average unbiased proportion correct for map and true categories was .642 and .647 respectively (Table 10), hence average errors of commission and omission were .358 and .353 respectively. In Table 10, errors of omission occur across rows and are summarized on the right; errors of commission occur in columns and are summarized across the bottom of the table.

This poor result was due to a high prevalence of themes with low accuracy. For example, Table 11 shows that πj for treed bog was 0.145. This means that 14.5% of classified pixels on the map were classified as treed bog, a substantial percentage. Table 10

Plate 1: Single-date thematic map of deer habitat for the study area.

Legend

Dark Blue - Water
Medium Blue - Fen with Surface Water
Light Blue - Marsh
Olive - Open Bog
Light Green - Softwood Forest
Dark Green - Treed Bog
Brown - Sand, Open Soil and Rock Outcrop
Red - Hardwood Forest
Orange - Mixed Forest
Lemon Yellow - Unimproved Pasture
Cream - Developed Agricultural Land
Pink - Shrubs and Early Successional Forest
Purple - Urban Area

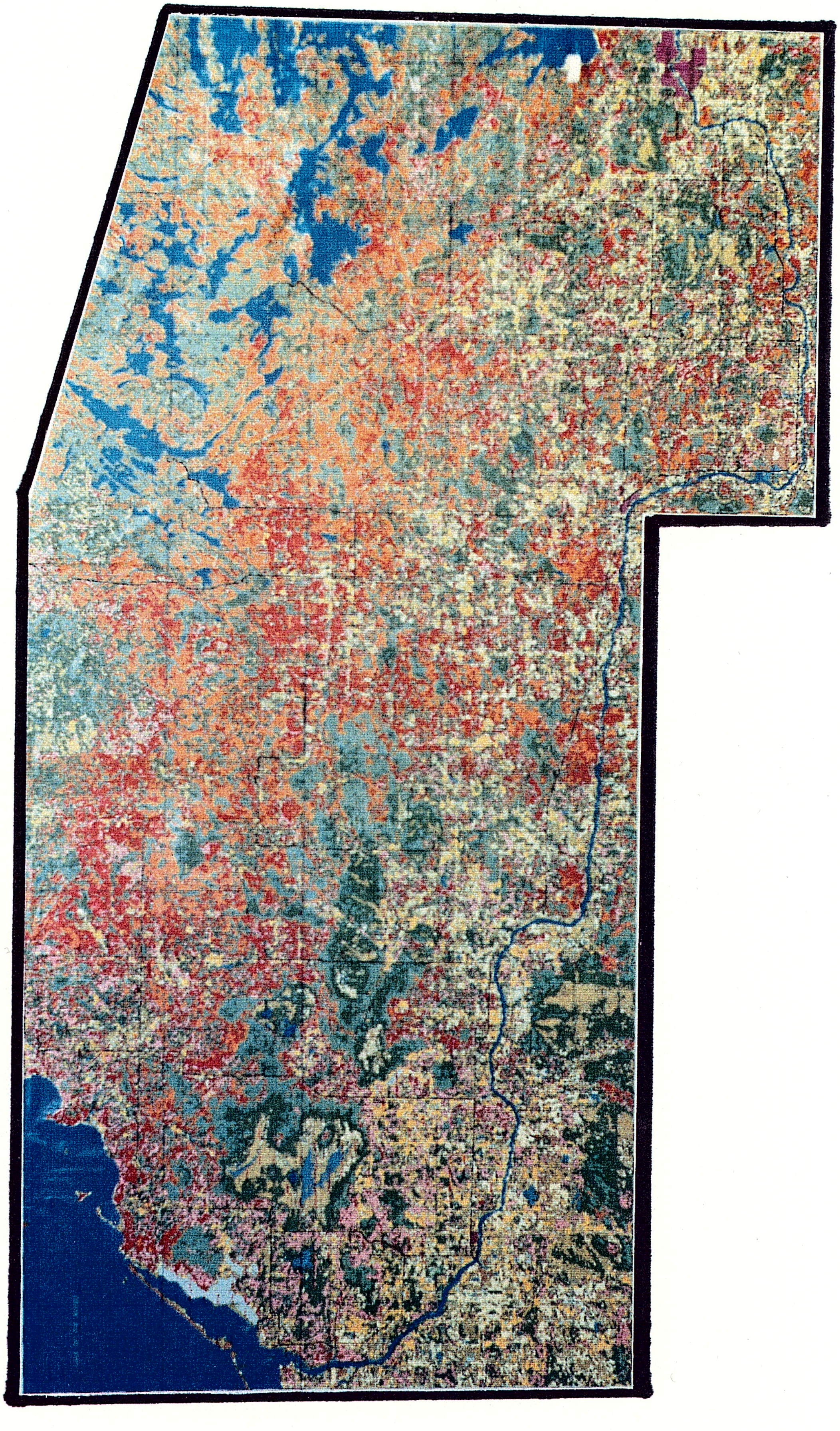

Table 10: Accuracy assessment results for the single-date thematic map.

True Category (i)	Map Category (j)*														
	Water	Marsh	Fen	Op Bog	Trd Bog	Sd/ Rock	Hwd For	Swd For	Mxd For	UP	DAL	ES	URB	Total ($n_{i.}$)	$\hat{\theta}_{ii}$ **
Water	50	0	2	0	0	9	0	0	0	0	0	0	0	61	.983
Marsh	0	47	0	0	0	0	0	0	0	0	0	0	0	47	1.000
Fen	0	0	37	0	0	0	0	1	0	0	0	0	0	38	.873
Op Bog	0	0	2	25	7	5	0	1	1	3	5	1	0	50	.338
Trd Bog	0	0	2	6	15	2	0	6	1	0	1	2	0	35	.644
Sd/Rock	0	0	0	0	0	16	0	0	0	1	0	0	0	17	.351
Hwd For	0	0	0	1	1	3	38	1	5	3	2	11	0	65	.587
Swd For	0	0	1	1	13	0	2	38	5	0	0	1	0	61	.411
Mxd For	0	0	0	0	7	4	6	0	38	0	0	4	0	59	.823
UP	0	0	3	2	0	0	0	0	0	11	4	2	0	22	.654
DAL	0	2	2	11	5	9	0	0	0	20	30	7	0	86	.433
ES	0	1	1	4	2	2	4	3	0	12	8	22	0	59	.317
URB	0	0	0	0	0	0	0	0	0	0	0	0	50	50	1.000
Total ($n_{.j}$)	50	50	50	50	50	50	50	50	50	50	50	50	50	650 (n)	.647
λ_j ***	1.00	.94	.74	.50	.30	.32	.76	.76	.76	.22	.60	.44	1.00	.642	

*: i = true category number 1,2,...,r;
j = map category number 1,2,...,r.

**: Unbiased proportion correct given true category 'i'. Calculated using the methods of Card (1982) from Table 11 cell entries to correct for differential sampling rate bias among map categories:

$\hat{\theta}_{ii} = \hat{P}_{ii} / \hat{P}_{i.}$ (Table 11).

***: $= n_{jj} / n_{.j}$, proportion correct given map category 'j' (after Card, 1982).

Table 11: Contingency table of estimated cell probabilities ($\hat{P}_{ij}$)* for calculating unbiased accuracy assessment of the single-date thematic map.

True Cat (i)	Map Category (j)												
	Water	Marsh	Fen	Op Bog	Trd Bog	Sd/ Rock	Hwd For	Swd For	Mxd For	UP	DAL	ES	URB
W	.068		.0005			.0007							
M		.0047											
F			.0089					.0013					
OB			.0005	.024	.0203	.0004		.0013	.0048	.0073	.0109	.0015	
TB			.0005	.0058	.0435	.0002		.0076	.0048		.0022	.0029	
SR						.0013				.0024			
HF				.001	.0029	.0002	.0813	.0013	.024	.0073	.0044	.0161	
SF			.0002	.001	.0377		.0043	.0479	.024			.0015	
MF					.0203	.0003	.0128		.1824			.0058	
UP			.0007	.0019						.0268	.0087	.0029	
DAL		.0002	.0005	.0106	.0145	.0007				.0488	.0654	.0102	
ES		.0001	.0002	.0038	.0058	.0002	.0086	.0038		.0293	.0174	.0321	
URB													.004
π_j**	.068	.005	.012	.048	.145	.004	.107	.063	.240	.122	.109	.073	.004

*: $\hat{P}_{ij} = \pi_j \; n_{ij} / n_{.j}$;
= proportion of pixels sampled and identified to cell ij in Table 10 weighted by π_j to correct for differential sampling rate bias,

**: $\pi_j = N_{.j} / N$;
= proportion of classified pixels in map category j for the entire study area (after Card, 1982). This was determined by a computer count of pixels on the thematic map.

shows that λj for treed bog was 0.30 and θii was 0.644. This means that unbiased proportion correct given map category was 30% and given true category it was 64.4%. This relatively common theme reduced overall accuracy considerably.

Similarly, unimproved pasture comprised 12.2% of total (Table 11), but had a map accuracy of 22% and an unbiased true accuracy of 65.4% (Table 10). Another example of a prevalent theme with poor accuracy is developed agricultural land (Tables 10 and 11).

Table 10 provides insight to the sources of confusion. For example, only 15 of 50 sample units of 3x3 pixels identified as treed bog on the map were indeed treed bog (black spruce, larch or cedar). Thirteen of the 50 were actually softwood forest (upland jack pine, red pine or white spruce), this being an error of commission within the map category 'treed bog'. Obviously there was poor differentiation between these themes during classification. Similarly, Table 10 shows confusion between unimproved pasture and developed agricultural land.

Table 10 also reveals that errors of omission are very common for hardwood forest (see true category row 'Hwd For'), but errors of commission are not (see map category column 'Hwd For'). Of 65 sample units that were truely hardwood forest, 11 show up on the map as shrubs and early successional forest (ES), 5 show up as mixed forest, etc. (Table 10). Errors of this type are not surprising given theme definitions being imposed, but they are unacceptably frequent.

It is important to note that if we combined the treed bog and softwood forest themes, and the unimproved pasture and developed agricultural themes, as was done for the multi-date map, unbiased overall accuracy is only increased to 69.3% (calculated from Table 11). Thus, overall accuracy of the single-date map was considered less than the acceptable threshold of 75% stated in the study hypothesis. Consequently, an attempt was made to improve accuracy by producing a new map using more than one date of imagery.

5.2 Multi-Date Imagery Production and Accuracy

The multi-date thematic map of deer habitat (Plate 2) was produced in March, 1985, using Landsat 3 and 4 MSS imagery from June 25, 1980 and May 8, 1983 respectively. Some haze in northern parts of the 1983 image required that only the near infrared bands of that imagery could be used during classification.

Scale of the map was 1:50,000 with 10 themes represented. Production quality was very good with the exception of a few small clouds in the southeastern portion of the map. Unbiased overall accuracy was substantially improved at 72.6 ± 4.6 % ($P<0.05$, Tables 12 and 13), but still less than the acceptable threshold of 75 %. Average unbiased proportion correct for map and true categories was .724 and .694 respectively (Table 13), with average errors of commission and omission being .276 and .316 respectively.

Plate 2: Multi-date thematic map of deer habitat for the study area.

Legend

Blue - Water (24,717 ha)
Buff - Open Wetlands (46,898 ha)
Light Green - Lowland Conifer Forest (41,672 ha)
Dark Green - Upland Conifer Forest (1,116 ha)
Red - Deciduous Forest (45,105 ha)
Orange - Mixed Forest (70,298 ha)
Lemon Yellow - Unimproved Pasture (19,042 ha)
Cream - Developed Agricultural Land (66,578 ha)
Pink - Shrubs and Early Successional Forest (32,361 ha)
Purple - Urban Areas (346 ha)

Table 12: Accuracy assessment results for the multi-date thematic map.

True Category (i)	Map Category (j)* Water	Open Wetld	Lowld Con For	Upld Con For	Dec For	Mxd For	UP	DAL	ES	URB	Total ($n_{i.}$)	$\hat{\theta}_{ii}$ **
Water	48	0	0	0	0	0	0	0	0	0	48	1.000
Op Wetld	2	36	3	0	0	1	2	0	2	0	46	.830
Low Con For	0	5	41	21	0	4	0	2	2	0	75	.699
Up Con For	0	1	0	25	1	0	0	0	0	0	27	.221
Dec For	0	1	0	0	44	2	5	1	5	0	58	.796
Mxd For	0	2	6	4	3	40	0	3	3	0	61	.783
UP	0	3	0	0	0	0	17	7	2	0	29	.327
DAL	0	2	0	0	0	0	14	27	2	0	45	.808
ES	0	0	0	0	2	3	12	10	34	0	61	.479
URB	0	0	0	0	0	0	0	0	0	50	50	1.000
Total ($n_{.j}$)	50	50	50	50	50	50	50	50	50	50	500 (n)	.694
λ_j ***	.96	.72	.82	.50	.88	.80	.34	.54	.68	1.00	.724	

*: i = true category number 1,2,...,r;
j = map category number 1,2,...,r.

**: Unbiased proportion correct given true category 'i'. Calculated using the methods of Card (1982) from Table 13 cell entries to correct for differential sampling rate bias among map categories:

$\hat{\theta}_{ii} = \hat{P}_{ii} / \hat{P}_{i.}$ (Table 13).

***: = $n_{jj}/n_{.j}$, proportion correct given map category 'j' (after Card, 1982).

Table 13: Contingency table of estimated cell probabilities ($\hat{P}_{ij}^{*}$) for calculating unbiased accuracy assessment of the multi-date thematic map.

True Category (i)	Map Category (j): Water	Open Wetld	Lowld Con	Upld Con	Dec For	Mxd For	UP	DAL	ES	URB
Water	.0672									
Op Wetld	.0028	.0972	.0072			.004	.0022		.0037	
Low Con		.0135	.0984	.0013		.0162		.0076	.0037	
Up Con		.0027		.0015	.0026					
Dec For		.0027			.1144	.0081	.0055	.0038	.0093	
Mxd For		.0054	.0144	.0002	.0078	.1616		.0115	.0056	
UP		.0081					.0187	.0267	.0037	
DAL		.0054					.0154	.1031	.0037	
ES					.0052	.0121	.0132	.0382	.0632	
URB										.001
π_j^{**}	.070	.135	.120	.003	.130	.202	.055	.191	.093	.001

*: $\hat{P}_{ij} = \pi_j \, n_{ij} / n_{.j}$;

= proportion of pixels sampled and identified to cell ij in Table 12 weighted by π_j to correct for differential sampling rate bias,

**: $\pi_j = N_{.j} / N$;

= proportion of classified pixels in map category j for the entire study area (after Card, 1982). This was determined by a computer count of pixels on the thematic map.

A substantial amount of error was due to confusion between unimproved pasture and developed agricultural land, and between upland coniferous and lowland coniferous forest themes (Table 12). It was decided to modify the multi-date thematic map by merging these four categories into two themes: unimproved pasture and developed agricultural land (UP & DAL), and coniferous forest (Con For).

Unbiased overall accuracy for the modified multi-date map was 77.0 $\pm$ 4.9 % ($P<0.05$, Tables 14 and 15). Average unbiased proportion correct was .820 and .808 for map and true categories respectively, with average rates of commission and omission error being .180 and .192 respectively (Table 14). Since this exceeded the 75% threshold, it was decided that overall accuracy of the modified map was acceptable. Subsequent prediction and testing of habitat suitability ranks was based on the modified multi-date thematic map.

Now let us examine accuracy of the multi-date map in more detail. The largest amount of error occurred with the unimproved pasture theme (UP). Only 17 of 50 3x3 pixel sample units identified on the map as UP were truely UP (Table 12). Serious errors of commission occurred in this UP column, 14 with DAL and 12 with ES. In some ways this is not surprising because the unimproved pasture training areas were old abandoned homesteads with long grass, herbaceous forbs and weeds growing in the fields. Training areas used for the UP theme did not include shrubs, but

Table 14: Accuracy assessment results for the modified multi-date thematic map.

True Category (i)	Map Category (j)* Water	Open Wetld	Con For	Dec For	Mxd For	UP & DAL	ES	URB	Total ($n_{i.}$)	$\hat{\theta}_{ii}$**
Water	48	0	0	0	0	0	0	0	48	1.000
Op Wetld	2	36	3	0	1	2	2	0	46	.830
Con For	0	6	87	1	4	2	2	0	102	.686
Dec For	0	1	0	44	2	6	5	0	58	.796
Mxd For	0	2	10	3	40	3	3	0	61	.783
UP & DAL	0	5	0	0	0	65	4	0	74	.887
ES	0	0	0	2	3	22	34	0	61	.479
URB	0	0	0	0	0	0	0	50	50	1.000
Total ($n_{.j}$)	50	50	100	50	50	100	50	50	500 (n)	.808
λ_j***	.96	.72	.87	.88	.80	.65	.68	1.00	.820	

*: i = true category number 1,2,...,r;
j = map category number 1,2,...,r.

**: Unbiased proportion correct given true category 'i'. Calculated using the methods of Card (1982) from Table 15 cell entries to correct for differential sampling rate bias among map categories:

$\hat{\theta}_{ii} = \hat{P}_{ii} / \hat{P}_{i.}$ (Table 15).

***: $= n_{jj}/n_{.j}$, proportion correct given map category 'j' (after Card, 1982).

Table 15: Contingency table of estimated cell probabilities ($\hat{P}_{ij}$)* for calculating unbiased accuracy assessment of the modified multi-date thematic map.

True Category (i)	Map Category (j)							
	Water	Open Wetld	Con For	Dec For	Mxd For	UP & DAL	ES	URB
Water	.0672							
Op Wetld	.0028	.0972	.0072		.004	.0022	.0037	
Con For		.0162	.1012	.0026	.0162	.0076	.0037	
Dec For		.0027		.1144	.0081	.0093	.0093	
Mxd For		.0054	.0146	.0078	.1616	.0115	.0056	
UP & DAL		.0135				.1639	.0074	
ES				.0052	.0121	.0514	.0632	
URB								.001
π_j**	.070	.135	.123	.130	.202	.246	.093	.001

*: $\hat{P}_{ij} = \pi_j \, n_{ij} / n_{.j}$;
= proportion of pixels sampled and identified to cell ij in Table 14 weighted by π_j to correct for differential sampling rate bias,

**: $\pi_j = N_{.j} / N$;
= proportion of classified pixels in map category j for the entire study area (after Card, 1982). This was determined by a computer count of pixels on the thematic map.

many unimproved pastures were experiencing encroachment by shrubs and deciduous saplings due to successional change. These situations constituted a biophysical gradient between the UP and ES themes. Similarly, hay fields before cropping comprised long grasses and lequmes, and constituted a biophysical gradient between the UP and DAL themes. The effect of these similarities on spectral signatures of the training areas will be discussed in Sec. 6.0.

Other substantial errors occurred with lowland conifer being mistaken for upland conifer (21 units, Table 12), and early successional forest being mistaken for DAL (10 sample units, Table 12). The former were errors of omission for lowland conifer but errors of commission for upland conifer. This means that when an upland conifer site was classified, the computer seldom if ever made the mistake of calling it lowland conifer; but it made many mistakes doing the opposite (21 of 50 sample units, Table 12).

Smaller amounts of error occurred between other themes, for example those in the open wetland row of Table 12. Again, confusion between open wetland and water, lowland conifer, unimproved pasture, or shrubs and early successional forest, is not too surprising given biophysical gradients between the types. This is also a likely source of error among the ES, mixed forest and deciduous forest themes.

The merger of UP and DAL, and of the coniferous forest themes, increased overall unbiased accuracy by 4.4% to 77.0% for the modified multi-date map. This left the ES theme being least accurate of the resulting eight themes (Table 14).

5.3 Predicted Habitat Ranks

Figures 5, 6 and 7 show arrays of predicted habitat suitability ranks for sq.km cells of the entire study area for winter, summer and year-round periods respectively. These predictions were based on computer evaluation of the modified multi-date map. Corresponding printouts of theme ranks (Tables 16-18) and of CATPROP and EI data (Table 19) allow more detailed evaluation of the habitat components in each sq.km cell. A rank of 1 represents optimum deer habitat; a rank of 5 represents unsatisfactory habitat.

Recall that predicted ranks were initially generated as integer values for simplicity of array production and interpretation. For Tests 1 to 3 these ranks were produced as numbers to two decimal places to satisfy the correlation assumption of bivariate normal distribution.

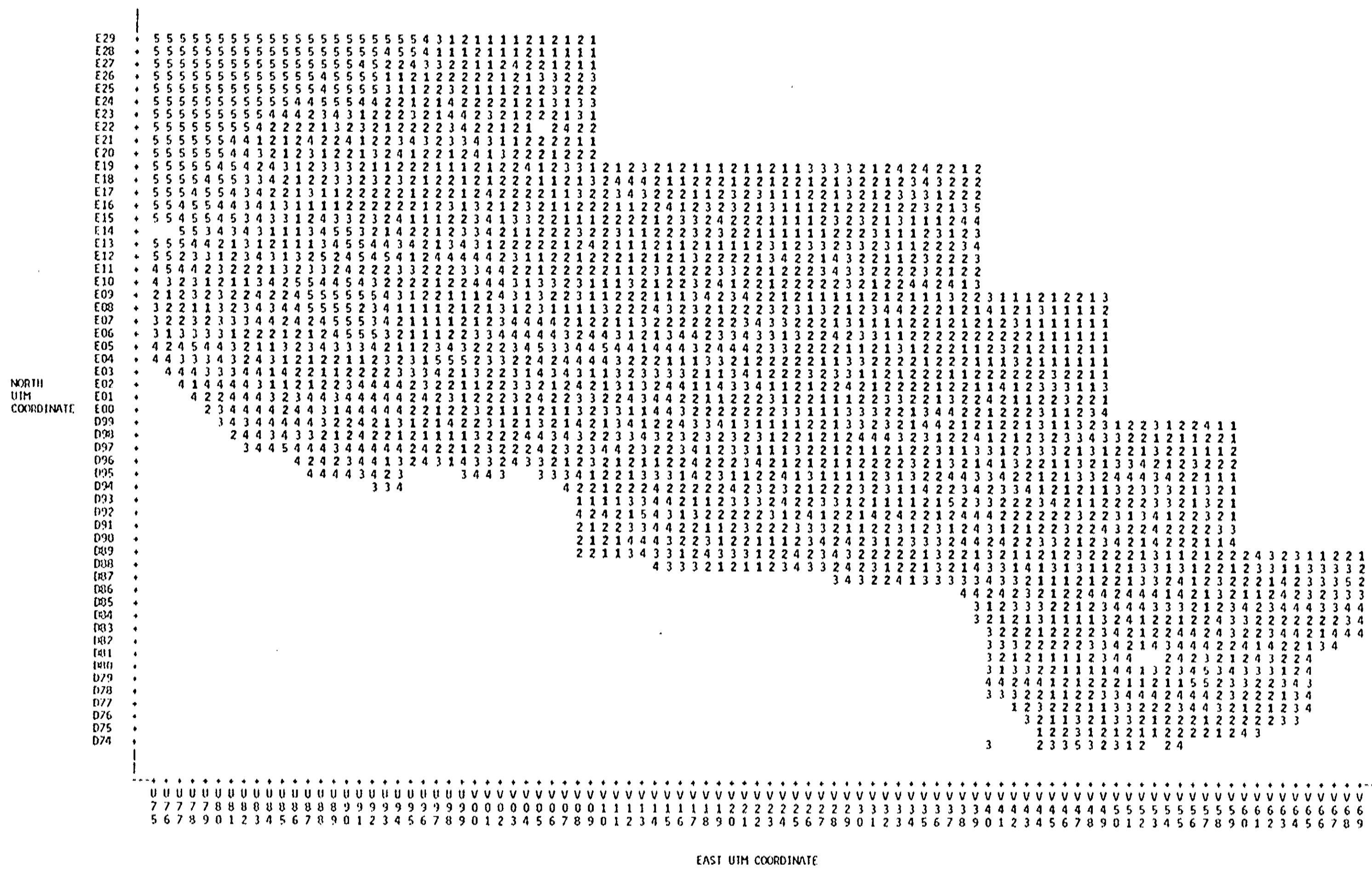

Fig. 5: Predicted winter habitat suitability ranks for sq.km cells of the study area by northern and eastern UTM coordinates. Cells with predicted rank 1 or 2 are in bold type for comparison with Figure 3.

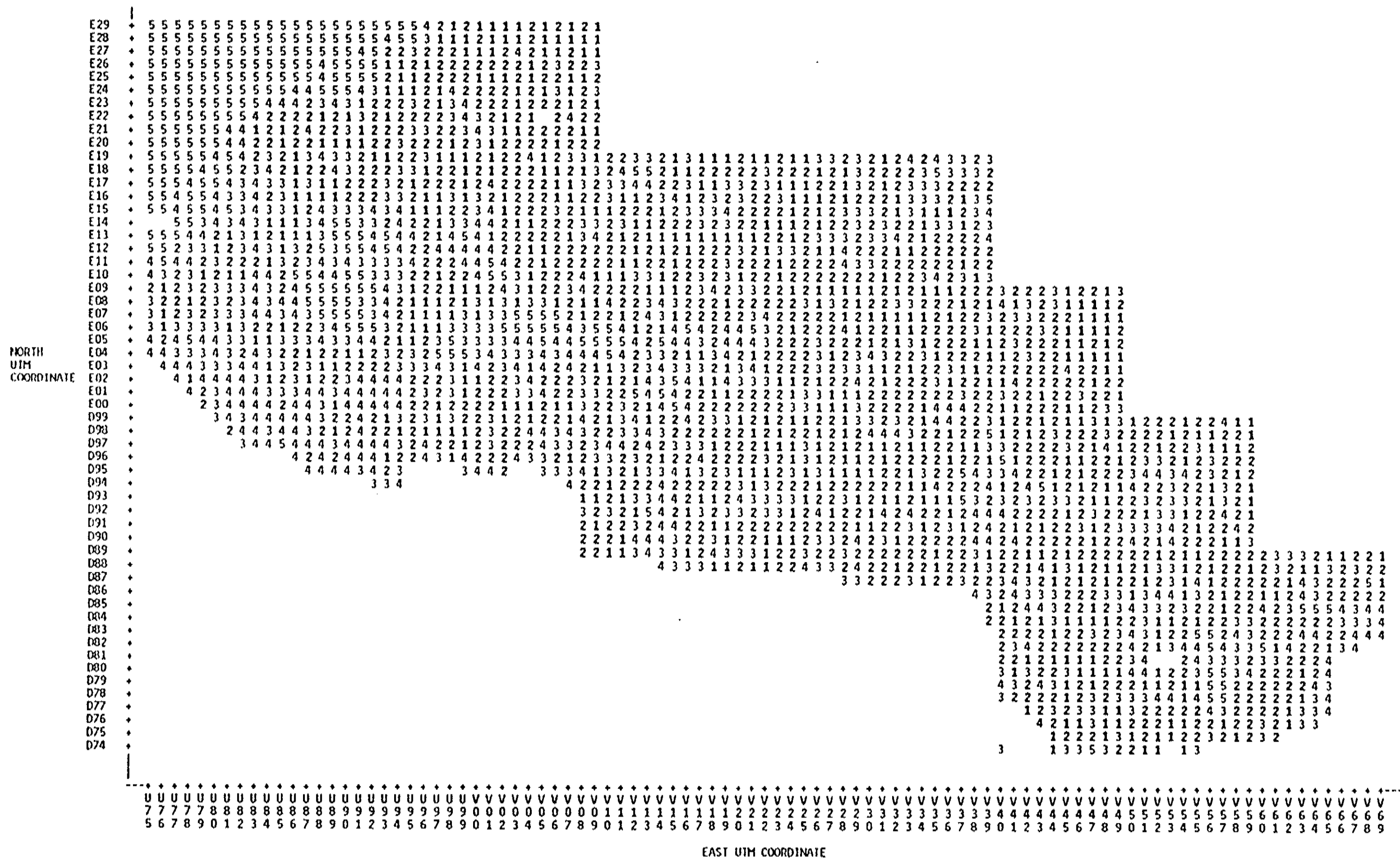

Fig. 6: Predicted summer habitat suitability ranks for sq.km cells of the study area by northern and eastern UTM coordinates. Cells with predicted rank 1 or 2 are in bold type.

Fig. 7: Predicted year-round habitat suitability ranks for sq.km cells of the study area by northern and eastern UTM coordinates. Cells with predicted rank 1 or 2 are in bold type.

Table16: Example of the predicted winter rank printout with ranks listed by sq. km UTM cell coordinate.

OBS	UTM	AVG RANK	WAT RANK1	OW RANK2	CON RANK34	DEC RANK5	MIX RANK6	UP&DAL RANK78	ES RANK9	URB RANK10	RANKEI	NORTH	EAST
1	UD8099	3	2	2	5	1	3	2	5	1	0	D99	U80
2	UD8198	2	2	2	5	1	4	3	5	1	-1	D98	U81
3	UD8199	4	1	1	3	1	4	4	5	1	1	D99	U81
4	UD8297	3	2	2	5	1	5	3	5	1	0	D97	U82
5	UD8298	4	2	1	5	1	4	4	5	1	1	D98	U82
6	UD8299	3	1	2	5	1	1	3	3	1	0	D99	U82
7	UD8397	4	2	2	5	1	4	2	5	3	1	D97	U83
8	UD8398	4	1	1	5	1	2	4	5	1	1	D98	U83
9	UD8399	4	1	1	5	1	5	5	5	1	1	D99	U83
10	UD8497	4	1	1	5	1	3	2	5	4	1	D97	U84
11	UD8498	3	1	2	4	1	1	3	4	1	0	D98	U84
12	UD8499	4	1	1	5	1	5	5	5	1	1	D99	U84
13	UD8597	5	1	1	5	1	5	4	5	3	1	D97	U85
14	UD8598	4	1	1	5	1	5	5	5	1	1	D98	U85
15	UD8599	4	1	1	5	1	1	4	4	1	1	D99	U85
16	UD8696	4	2	2	5	1	4	3	4	1	1	D96	U86
17	UD8697	4	1	1	5	1	5	5	5	1	1	D97	U86
18	UD8698	3	1	1	3	1	1	4	4	1	1	D98	U86
19	UD8699	4	1	1	5	1	2	5	5	1	1	D99	U86
20	UD8795	4	2	1	5	1	3	3	3	1	1	D95	U87
21	UD8796	2	1	1	5	1	1	3	1	1	0	D96	U87
22	UD8797	4	1	2	4	1	3	4	4	1	1	D97	U87
23	UD8798	3	1	2	5	1	4	4	5	1	0	D98	U87
24	UD8799	4	1	1	5	1	5	5	5	1	1	D99	U87
25	UD8895	4	1	2	5	1	5	4	5	1	1	D95	U88
26	UD8896	4	1	2	5	1	5	4	5	1	1	D96	U88
27	UD8897	4	1	1	5	1	4	4	2	1	1	D97	U88
28	UD8898	2	1	1	5	1	1	3	1	1	0	D98	U88
29	UD8899	3	1	1	5	1	1	4	1	1	1	D99	U88
30	UD8995	4	1	1	5	1	4	3	1	1	1	D95	U89
31	UD8996	2	1	1	5	1	1	3	1	1	0	D96	U89
32	UD8997	3	1	1	5	1	1	3	1	1	1	D97	U89
33	UD8998	1	1	1	1	1	1	2	1	1	-1	D98	U89
34	UD8999	2	1	1	4	1	1	3	1	1	0	D99	U89
35	UD9095	4	1	1	5	1	4	4	1	1	1	D95	U90
36	UD9096	3	1	1	4	1	3	4	1	1	1	D96	U90
37	UD9097	4	1	1	5	1	5	5	5	1	1	D97	U90
38	UD9098	2	1	1	5	1	1	4	2	1	0	D98	U90
39	UD9099	2	1	1	3	1	2	4	1	1	0	D99	U90
40	UD9195	3	1	1	5	1	4	4	1	1	0	D95	U91
41	UD9196	4	1	2	5	1	5	4	4	1	1	D96	U91
42	UD9197	4	1	1	5	1	5	5	5	1	1	D97	U91
43	UD9198	4	1	1	5	1	5	5	4	1	1	D98	U91
44	UD9199	4	1	2	5	1	4	4	4	1	1	D99	U91
45	UD9294	3	2	2	5	1	4	2	1	1	0	D94	U92
46	UD9295	4	1	2	5	1	5	4	3	1	1	D95	U92
47	UD9296	4	1	2	5	1	3	3	1	1	1	D96	U92
48	UD9297	4	1	1	5	1	4	4	1	1	1	D97	U92
49	UD9298	2	1	1	5	1	1	3	1	1	0	D98	U92
50	UD9299	2	1	1	2	1	1	2	1	1	0	D99	U92

Table 17: Example of the predicted summer rank printout with ranks listed by sq. km UTM cell coordinate.

OBS	UTM	AVG RANK	WAT RANK1	OW RANK2	CON RANK34	DEC RANK5	MIX RANK6	UP&DAL RANK78	FS RANK9	URB RANK10	RANKEI	NORTH	EAST
1	UD8099	3	2	2	1	5	3	2	5	1	0	D99	U80
2	UD8198	2	2	2	1	5	4	3	5	1	-1	D98	U81
3	UD8199	4	1	1	1	5	4	4	5	1	1	D99	U81
4	UD8297	3	2	2	1	5	5	3	5	1	0	D97	U82
5	UD8298	4	2	1	1	5	4	4	5	1	1	D98	U82
6	UD8299	3	1	2	1	5	1	3	3	1	0	D99	U82
7	UD8397	4	2	2	1	5	4	2	5	3	1	D97	U83
8	UD8398	4	1	1	1	5	2	4	5	1	1	D98	U83
9	UD8399	4	1	1	1	5	5	5	5	1	1	D99	U83
10	UD8497	4	1	1	1	5	3	2	5	4	1	D97	U84
11	UD8498	3	1	2	1	5	1	3	4	1	0	D98	U84
12	UD8499	4	1	1	1	5	5	5	5	1	1	D99	U84
13	UD8597	5	1	1	1	5	5	4	5	3	1	D97	U85
14	UD8598	4	1	1	1	5	5	5	5	1	1	D98	U85
15	UD8599	4	1	1	1	5	1	4	4	1	1	D99	U85
16	UD8696	4	2	2	1	5	4	3	4	1	1	D96	U86
17	UD8697	4	1	1	1	5	5	5	5	1	1	D97	U86
18	UD8698	4	1	1	1	5	1	4	4	1	1	D98	U86
19	UD8699	4	1	1	1	5	2	5	5	1	1	D99	U86
20	UD8795	4	2	1	1	5	3	3	3	1	1	D95	U87
21	UD8796	2	1	1	1	1	1	3	1	1	0	D96	U87
22	UD8797	4	1	2	1	5	3	4	4	1	1	D97	U87
23	UD8798	3	1	2	1	5	4	4	5	1	0	D98	U87
24	UD8799	4	1	1	1	5	5	5	5	1	1	D99	U87
25	UD8895	4	1	2	1	5	5	4	5	1	1	D95	U88
26	UD8896	4	1	2	1	5	5	4	5	1	1	D96	U88
27	UD8897	4	1	1	1	5	4	4	2	1	1	D97	U88
28	UD8898	2	1	1	1	5	1	3	1	1	0	D98	U88
29	UD8899	3	1	1	1	5	1	4	1	1	1	D99	U88
30	UD8995	4	1	1	1	5	4	3	1	1	1	D95	U89
31	UD8996	2	1	1	1	5	1	3	1	1	0	D96	U89
32	UD8997	3	1	1	1	5	1	3	1	1	1	D97	U89
33	UD8998	1	1	1	1	5	1	2	1	1	-1	D98	U89
34	UD8999	2	1	1	1	5	1	3	1	1	0	D99	U89
35	UD9095	4	1	1	1	5	4	4	1	1	1	D95	U90
36	UD9096	4	1	1	1	5	3	4	1	1	1	D96	U90
37	UD9097	4	1	1	1	5	5	5	5	1	1	D97	U90
38	UD9098	2	1	1	1	5	1	4	2	1	0	D98	U90
39	UD9099	2	1	1	1	5	2	4	1	1	0	D99	U90
40	UD9195	3	1	1	1	5	4	4	1	1	0	D95	U91
41	UD9196	4	1	2	1	5	5	4	4	1	1	D96	U91
42	UD9197	4	1	1	1	5	5	5	5	1	1	D97	U91
43	UD9198	4	1	1	1	5	5	5	4	1	1	D98	U91
44	UD9199	4	1	2	1	5	4	4	4	1	1	D99	U91
45	UD9294	3	2	2	1	5	4	2	1	1	0	D94	U92
46	UD9295	4	1	2	1	5	5	4	3	1	1	D95	U92
47	UD9296	4	1	2	1	5	3	3	1	1	1	D96	U92
48	UD9297	4	1	1	1	4	4	4	1	1	1	D97	U92
49	UD9298	2	1	1	1	4	1	3	1	1	0	D98	U92
50	UD9299	2	1	1	1	3	1	2	1	1	0	D99	U92

Table 18 : Example of the predicted year-round rank printout with ranks listed by sq.km UTM cell coordinates.

OBS	UTM	AVG RANK	WA RANK1	OW RANK2	CON RANK34	DEC RANK5	MIX RANK6	UP&DAL RANK78	ES RANK9	URB RANK10	RANKEI	NORTH	EAST
1	UD8099	4	2	2	5	5	3	2	5	1	0	D99	U80
2	UD8198	3	2	2	5	5	4	3	5	1	-1	D98	U81
3	UD8199	4	1	1	3	5	4	4	5	1	1	D99	U81
4	UD8297	4	2	2	5	5	5	3	5	1	0	D97	U82
5	UD8298	5	2	1	5	5	4	4	5	1	1	D98	U82
6	UD8299	3	1	2	5	5	1	3	3	1	0	D99	U82
7	UD8397	5	2	2	5	5	4	2	5	3	1	D97	U83
8	UD8398	4	1	1	5	5	2	4	5	1	1	D98	U83
9	UD8399	5	1	1	5	5	5	5	5	1	1	D99	U83
10	UD8497	5	1	1	5	5	3	2	5	4	1	D97	U84
11	UD8498	3	1	2	4	5	1	3	4	1	0	D98	U84
12	UD8499	5	1	1	5	5	5	5	5	1	1	D99	U84
13	UD8597	5	1	1	5	5	5	4	5	3	1	D97	U85
14	UD8598	5	1	1	5	5	5	5	5	1	1	D98	U85
15	UD8599	4	1	1	5	5	1	4	4	1	1	D99	U85
16	UD8696	5	2	2	5	5	4	3	4	1	1	D96	U86
17	UD8697	5	1	1	5	5	5	5	5	1	1	D97	U86
18	UD8698	4	1	1	3	5	1	4	4	1	1	D98	U86
19	UD8699	5	1	1	5	5	2	5	5	1	1	D99	U86
20	UD8795	4	2	1	5	5	3	3	3	1	1	D95	U87
21	UD8796	2	1	1	5	1	1	3	1	1	0	D96	U87
22	UD8797	4	1	2	4	5	3	4	4	1	1	D97	U87
23	UD8798	4	1	2	5	5	4	4	5	1	0	D98	U87
24	UD8799	5	1	1	5	5	5	5	5	1	1	D99	U87
25	UD8895	5	1	2	5	5	5	4	5	1	1	D95	U88
26	UD8896	5	1	2	5	5	5	4	5	1	1	D96	U88
27	UD8897	4	1	1	5	5	4	4	2	1	1	D97	U88
28	UD8898	3	1	1	5	5	1	3	1	1	0	D98	U88
29	UD8899	4	1	1	5	5	1	4	1	1	1	D99	U88
30	UD8995	4	1	1	5	5	4	3	1	1	1	D95	U89
31	UD8996	3	1	1	5	5	1	3	1	1	0	D96	U89
32	UD8997	4	1	1	5	5	1	3	1	1	1	D97	U89
33	UD8998	1	1	1	1	5	1	2	1	1	-1	D98	U89
34	UD8999	3	1	1	4	5	1	3	1	1	0	D99	U89
35	UD9095	4	1	1	5	5	4	4	1	1	1	D95	U90
36	UD9096	4	1	1	4	5	3	4	1	1	1	D96	U90
37	UD9097	5	1	1	5	5	5	5	5	1	1	D97	U90
38	UD9098	3	1	1	5	5	1	4	2	1	0	D98	U90
39	UD9099	3	1	1	3	5	2	4	1	1	0	D99	U90
40	UD9195	3	1	1	5	5	4	4	1	1	0	D95	U91
41	UD9196	5	1	2	5	5	5	4	4	1	1	D96	U91
42	UD9197	5	1	1	5	5	5	5	5	1	1	D97	U91
43	UD9198	5	1	1	5	5	5	5	4	1	1	D98	U91
44	UD9199	5	1	2	5	5	4	4	4	1	1	D99	U91
45	UD9294	3	2	2	5	5	4	2	1	1	0	D94	U92
46	UD9295	5	1	2	5	5	5	4	3	1	1	D95	U92
47	UD9296	4	1	2	5	5	3	3	1	1	1	D96	U92
48	UD9297	4	1	1	5	4	4	4	1	1	1	D97	U92
49	UD9298	3	1	1	5	4	1	3	1	1	0	D98	U92
50	UD9299	2	1	1	2	3	1	2	1	1	0	D99	U92

Table 19: Example of the printout of satellite-derived CATPROP and EI data by sq.km UTM cell coordinate.

OBS	UTM	WA	OW	LC	UC	DE	MIX	UP	DAL	ES	URB	UC	EI	NORTH	EAST
1	UD8099	28.0	32.3	0.0	0	0.5	5.8	2.0	31.5	0.0	0.0	0.0	14	D99	U80
2	UD8198	24.8	23.0	0.3	0	0.0	3.5	17.8	28.8	2.0	0.0	0.0	22	D98	U81
3	UD8199	12.0	12.3	6.0	0	0.0	4.8	9.5	54.5	1.0	0.0	0.0	11	D99	U81
4	UD8297	23.0	18.8	0.0	0	0.0	0.0	16.5	41.3	0.0	0.0	0.5	16	D97	U82
5	UD8298	22.3	14.0	0.0	0	0.0	3.0	16.5	44.3	0.0	0.0	0.0	9	D98	U82
6	UD8299	0.0	33.3	2.3	0	0.0	11.3	5.3	39.8	8.3	0.0	0.0	15	D99	U82
7	UD8397	16.5	15.8	0.0	0	0.0	4.3	12.0	25.0	1.3	25.3	0.0	6	D97	U83
8	UD8398	0.0	14.3	0.0	0	0.0	7.5	22.3	54.8	1.3	0.0	0.0	6	D98	U83
9	UD8399	0.0	10.5	0.0	0	0.0	0.5	12.5	76.5	0.0	0.0	0.0	9	D99	U83
10	UD8497	2.0	0.8	0.0	0	0.0	6.3	4.0	30.8	2.0	54.3	0.0	8	D97	U84
11	UD8498	2.8	18.8	4.8	0	0.0	21.0	9.8	37.3	5.8	0.0	0.0	15	D98	U84
12	UD8499	0.0	10.0	1.5	0	0.0	0.8	20.3	67.5	0.0	0.0	0.0	3	D99	U84
13	UD8597	0.0	3.5	0.0	0	0.0	0.0	24.5	38.3	0.8	33.0	0.0	8	D97	U85
14	UD8598	0.0	0.0	0.8	0	0.0	1.5	20.0	75.5	2.3	0.0	0.0	8	D98	U85
15	UD8599	0.0	0.0	0.5	0	0.0	22.3	16.0	56.5	4.8	0.0	0.0	9	D99	U85
16	UD8696	23.0	16.0	0.0	0	0.0	3.3	10.0	43.0	4.8	0.0	0.0	12	D96	U86
17	UD8697	0.0	7.8	0.0	0	0.0	0.5	19.8	69.0	3.0	0.0	0.0	3	D97	U86
18	UD8698	0.0	3.5	5.0	0	0.0	18.8	8.8	58.0	6.0	0.0	0.0	11	D98	U86
19	UD8699	0.0	7.0	1.3	0	0.0	8.3	16.3	67.3	0.0	0.0	0.0	5	D99	U86
20	UD8795	17.8	12.5	0.0	0	0.0	5.8	19.8	35.8	8.5	0.0	0.0	12	D95	U87
21	UD8796	0.0	0.3	0.0	0	5.5	26.2	12.0	31.5	24.5	0.0	0.0	16	D96	U87
22	UD8797	0.0	20.0	2.8	0	0.0	6.0	24.3	43.3	3.8	0.0	0.0	9	D97	U87
23	UD8798	0.0	16.5	0.0	0	0.0	3.8	32.8	45.5	1.5	0.0	0.0	16	D98	U87
24	UD8799	0.0	10.8	0.0	0	0.0	0.0	34.0	52.5	2.8	0.0	0.0	7	D99	U87
25	UD8895	14.0	15.3	0.0	0	0.0	0.0	18.8	52.0	0.0	0.0	0.0	8	D95	U88
26	UD8896	0.0	33.3	0.0	0	0.0	0.8	12.5	52.7	0.8	0.0	0.0	11	D96	U88
27	UD8897	0.0	7.0	0.0	0	0.0	3.3	26.0	52.5	11.3	0.0	0.0	12	D97	U88
28	UD8898	0.0	7.3	1.3	0	0.0	10.5	21.3	24.3	35.5	0.0	0.0	20	D98	U88
29	UD8899	0.0	0.0	0.0	0	0.0	12.5	23.5	45.3	18.8	0.0	0.0	12	D99	U88
30	UD8995	2.0	8.0	0.0	0	1.0	2.8	23.0	35.8	27.5	0.0	0.0	8	D95	U89
31	UD8996	0.0	7.3	2.3	0	0.0	19.5	4.0	47.0	19.5	0.0	0.5	19	D96	U89
32	UD8997	0.0	3.0	0.5	0	0.0	24.5	13.0	41.8	17.3	0.0	0.0	12	D97	U89
33	UD8998	0.0	5.8	10.3	0	0.8	24.8	11.5	20.5	26.5	0.0	0.0	21	D98	U89
34	UD8999	0.0	0.3	2.5	0	0.0	11.0	28.0	27.8	30.5	0.0	0.0	13	D99	U89
35	UD9095	0.0	4.0	1.5	0	0.0	2.8	28.3	47.0	16.5	0.0	0.0	5	D95	U90
36	UD9096	0.0	6.8	4.3	0	0.0	5.3	21.8	45.0	17.0	0.0	0.0	5	D96	U90
37	UD9097	0.0	8.3	0.0	0	0.0	1.5	21.8	65.5	3.0	0.0	0.0	2	D97	U90
38	UD9098	0.0	8.8	1.0	0	0.0	12.8	22.3	41.0	14.3	0.0	0.0	16	D98	U90
39	UD9099	0.0	0.3	5.8	0	0.0	9.8	16.8	44.0	23.5	0.0	0.0	20	D99	U90
40	UD9195	0.0	11.3	0.0	0	0.0	2.5	22.8	44.5	19.0	0.0	0.0	13	D95	U91
41	UD9196	0.0	19.0	0.8	0	0.0	0.0	19.8	53.5	5.8	0.0	1.3	7	D96	U91
42	UD9197	0.0	3.8	0.5	0	0.0	0.0	25.3	68.3	2.3	0.0	0.0	2	D97	U91
43	UD9198	0.0	5.3	0.3	0	0.0	0.0	16.0	73.0	5.5	0.0	0.0	5	D98	U91
44	UD9199	0.0	21.3	0.0	0	0.0	4.0	14.3	54.3	6.3	0.0	0.0	9	D99	U91
45	UD9294	20.5	20.0	0.0	0	0.0	4.0	8.8	29.5	17.3	0.0	0.0	14	D94	U92
46	UD9295	0.0	21.8	0.3	0	0.8	0.8	20.0	46.8	9.8	0.0	0.0	11	D95	U92
47	UD9296	0.0	15.5	0.0	0	0.0	7.0	11.0	39.3	27.3	0.0	0.0	10	D96	U92
48	UD9297	0.0	4.8	0.0	0	1.3	2.8	26.2	49.0	16.0	0.0	0.0	11	D97	U92
49	UD9298	0.0	9.3	0.5	0	2.3	15.3	26.0	29.0	17.8	0.0	0.0	20	D98	U92
50	UD9299	0.0	2.5	9.3	0	2.5	19.0	14.5	25.5	26.8	0.0	0.0	17	D99	U92

Now let us examine how these figures and tables can be interpreted. Each of Figures 5 to 7 portrays an array of predicted habitat suitability ranks for a given season or year-round period. Each array represents the study area in shape and outline, although compressed in width. Each cell of an array represents one sq.km of the study area. The number in each cell is the habitat suitability rank for that period. The coordinates on the ordinate and abscissal axes are north and east coordinates of the UTM grid found on 1:50,000 topographical maps of the study area. They can be cross-referenced to the UTM coordinate designator for each sq.km cell by referring to any of Tables 16-18.

For example, locate UTM cell UD8795 (Obs. 20) in Table 16. Note that it has a north coordinate of D95 and an east coordinate of U87. It is found in Figures 5 to 7 on the bottom margin of the array 13 columns in from the left side.

In each of Figures 5 to 7, UD8795 has a predicted rank of 4 (poor). Table 16 shows that it ranks reasonably well (1 to 3) as winter habitat for every theme except coniferous forest which ranks 5, and edge index which ranks +1. Now turn to Table 19. Here you can see that the percentage of total area in either lowland or coniferous forest is predicted to be zero. Mixed forest is predicted to comprise only 5.8% of total area. Thus, one major problem predicted for this sq.km for winter habitat is a serious shortage of coniferous cover for deer. Another is that the number of edge intersects is 12, less than the mid-range, 13 to 20, for the study area (Sec.4.3). Thus, a value of +1 was added to the average of theme ranks. Note that EI exerts a more powerful influence on predicted rank than any one theme.

As summer habitat it does not appear to fare any better. Figure 6 gives it a predicted summer rank of 4. Table 17 shows that it ranks a 3 for UP&DAL and a 3 for ES. Deciduous forest also ranks very low, at 5, and EI is +1. Table 25 explains why. In the row beside UD8795 (Obs.20) we see that UP is predicted to comprise 19.8% of the sq.km, DAL to be 35.8% and ES to be only 8.5%. The table predicts there is no deciduous forest and the amount of edge is 12 intersects, less than the 13 to 20 mid-range for the study area. These characteristics are substantially less than optimal for white-tailed deer. Table 8 shows that optimal summer habitat should contain 3 to 20% UP&DAL, 15 to 55% ES and 5 to 15% deciduous. Hence the low predicted summer rank. The amount of cleared land is predicted to be excessive, and the amounts of early successional or deciduous forest are either too small or non-existent.

Let us try another cell. Find UD8998 (Obs.33) in Table 16. It has a predicted winter rank of 1 and is found in Figure 5 two columns to the right and three rows up from the previous cell. Figures 6 and 7 show that predicted summer and year-round ranks for UD8998 are also 1. Why is it predicted to be optimal?

Table 16 shows that it ranks 1 for all themes in winter except UP&DAL=2 and EI=-1. Table 19 shows that the amount of UP&DAL combined is predicted to be 32.0%, more than the maximum optimal value of 20% (Table 8). There was, however, an above average amount of edge (21 intersects). This more than compensated for the higher than optimal amount of open field, and predicted winter rank was calculated to be 1.

Table 17 shows that predicted summer rank for UD8998 (Obs.33) is also 1. The only theme ranks departing from optimal are deciduous forest (5) and UP&DAL (2). Edge index is -1. Table 19 explains this. Deciduous forest is predicted to comprise only 0.8%, less than the optimal 5 to 15%, and UP&DAL combined comprise 32.0%, more than optimal. Again, the high edge count (21) compensates for this and predicted summer rank is calculated to be 1.

5.4 Test 1 - Correlation with Independently Measured Ranks

Covariances and correlations between the sample of predicted year-round ranks (PYRR) and Test 1 ranks (T1YR or truth) are shown in Table 20. Both sets of ranks were generated to two decimal places (Appendices 5 and 6). The correlation was highly significant (P=0.0001) with correlation coefficient R=0.78484. When expressed as a simple linear regression of predicted year-round rank on Test 1 rank, the result was highly significant

(P=0.0001) with coefficient of determination R-squared=0.6160 (Table 21). In other words, 61.6 % of the variability in predicted ranks was explained by 'true' differences in suitablility of the spatial pattern, or mosaic, of important habitat types (Table 8).

Table 20: Covariances and correlations between predicted year-round habitat suitability ranks (PYRR) and Test 1 ranks (T1YR) for a simple random sample of sq.km UTM cells.

Statistic	Variable	Variable PYRR	 T1YR
Covariance	PYRR	1.47325	1.04382
Covariance	T1YR	1.04382	1.20063
Mean		2.27439	2.33818
Std Deviation		1.21378	1.09573
N		66	66
Correlation	PYRR	1	0.78484
Correlation	T1YR	0.78484	1

Note also in Table 20, that the mean predicted year-round rank was 2.274 compared to a mean Test1 rank of 2.338. The standard deviations of these means were reasonably similar. This is evidence that, on average, the predicted year-round ranks closely approximate 'truth', thus supporting the concept of predicting habitat suitability ranks from satellite imagery data.

Table 21: Analysis of variance and regression statistics for the simple linear regression of predicted year-round habitat suitability rank (PYRR) on Test 1 rank (T1YR) for a simple random sample of sq.km UTM cells.

ANALYSIS OF VARIANCE

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE	PROB>F
Model	1	58.98623	58.98623	102.654	0.0001
Error	64	36.77520	0.57461		
C Total	65	95.76143			

ROOT MSE	0.75803	R-SQUARE	0.6160
DEP MEAN	2.27439	ADJ R-SQ	0.6100
C.V.	33.32897		

PARAMETER ESTIMATES

VARIABLE	DF	PARAMETER ESTIMATE	STANDARD ERROR	T FOR H0: PARAMETER=0	PROB>|T|
INTERCEPT	1	0.24161	0.22127	1.092	0.2790
T1YR	1	0.86939	0.08581	10.132	0.0001

The results of Test 1 support acceptance of the first part of the study hypothesis that "predictions of habitat suitability derived from an MSS thematic map of white-tailed deer habitat of minimum 75% accuracy are significantly (P<0.05) correlated with independent measures of habitat mosaic suitability...". Predicted year-round ranks generated to two decimal places did evaluate the habitat mosaic for white-tailed deer, with a reliability of 61.6%.

However, the predicted ranks represent information obtained from light reflected from the top of the forest canopy. They must also be tested against factors in the forest understory and on the ground that are of more direct importance to deer. Test 2 was designed to do this.

5.5 Test 2 - Correlation with Food, Cover and Site Data from Field Sampling

Food, cover and site data were collected for 33 variables (Appendix 3) on approximately 2500 random plots on a simple random sample of sq.km cells of the study area (n=66, Figure 2). This resulted in a very large dataset 80 columns by 10,881 rows in size. These raw field data were summarized into 15 variable measurements for each of the 66 cells (Table 9) for Test 2.

The canonical correlation procedure was performed first between Test 1 ranks (T1YR) and Test 2 summary data. This was done to help evaluate the results of Test 2. The canonical correlation between Test 1 and 2 data was 0.7355 and highly significant (P=0.0001). This means that 54.1 % of the variability in Test 1 ranks was explained by the dataset of Test 2 summary variables (Squared CC, Table 22). A complete report of these results is given in Appendix 9.

The same procedure was done between the predicted year-round ranks (PYRR) and Test 2 ranks. Surprisingly, the canonical correlation was 0.7844 (P=0.0001, Table 23), higher than that with Test 1 ranks. Hence, 61.5 % of the variability in predicted ranks was explained by the Test 2 summary dataset (Squared CC, Table 23). A complete report of PYRR-Test2 canonical correlation results is given in Appendix 10.

Table 22: Results of the canonical correlation of Test 1 year-round ranks (T1YR) with Test 2 summary data for a simple random sample of sq.km UTM cells.

CANONICAL CORRELATION	ADJUSTED CANONICAL CORRELATION	APPROX STANDARD ERROR	SQUARED CANONICAL CORRELATION	EIGENVALUE
0.73552	0.67091	0.05693	0.54099	1.1786

TEST OF HO: THE CANONICAL CORRELATION IS ZERO

LIKELIHOOD RATIO	F	DF	DEN DF	PR > F
0.45901	3.9286	15	50	0.0001

Table 23: Results of the canonical correlation of predicted year-round habitat suitability ranks (PYRR) with Test 2 summary data for a simple random sample of sq.km UTM cells.

CANONICAL CORRELATION	ADJUSTED CANONICAL CORRELATION	APPROX STANDARD ERROR	SQUARED CANONICAL CORRELATION	EIGENVALUE
0.78442	0.73393	0.04772	0.61531	1.5995

TEST OF HO: THE CANONICAL CORRELATION IS ZERO

LIKELIHOOD RATIO	F	DF	DEN DF	PR > F
0.38469	5.3317	15	50	0.0001

SIMPLE CORRELATIONS (R) BETWEEN THE PREDICTED RANKS AND THE TEST2 SUMMARY VARIABLES *

	NTHEME	NDOMTREE	MTBA	MCBA	MSCBA	MSTDAGE	MSTDHT
PYRR	-0.5457	-0.6143	-0.4394	-0.0591	-0.2351	-0.3319	-0.5555
	MFERT	MSLOPE	MASPECT	MCCC	MNBSP	MBD	MNHSP
PYRR	-0.4383	-0.2249	-0.2450	-0.1556	-0.6629	-0.3241	-0.5569
	MHD						
PYRR	-0.1320						

*: For definitions of summary variables see Table 9.

Simple correlations between the predicted year-round ranks and the Test 2 summary variables showed that correlation was best with 'mean number of important browse species per plot' (R=-0.6629), followed by 'number of changes in dominant tree species per sq.km' (R=-0.6143) and 'mean number of important herbaceous forage species per plot' (R=-0.5569) (Table 23). Interestingly, all of these are measures of diversity that are very important for white-tailed deer.

Other reasonably strong correlations were with 'mean stand height per plot' (R=-0.5555), 'number of changes in habitat theme per sq.km sampled' (R=-0.5457), 'mean total basal area per plot' (R=-0.4394) and 'mean soil fertility per plot' (R=-0.4383) (Table 23). All correlations were negative because, with the exception of mean soil fertility, as variable values increased the predicted rank improved by getting smaller. Mean soil fertility will be discussed later.

The results of Test 2 support acceptance of the second part of the study hypothesis, that "predictions of habitat suitability ... are significantly (P<0.05) correlated with independent measures of ... deer forage, cover and site characteristics".

The canonical correlation on Test 1 ranks (T1YR) and Test 2 data was conducted as a back-up validity check of the Test 2 summary data. Had there not been a significant and reasonably strong correlation, validity of one or both of the datasets would have been suspect. As it was, the correlation was significant and reasonably strong, and fairly close to the PYRR-Test2 result. This indicates that both Test 1 and 2 datasets were valid.

5.6 Test 3 - Correlation with Over-Winter Deer Density Distribution

Correlation between predicted winter habitat suitability rank and winter deer density distribuiton was determined for a stratified random sample of sq.km UTM cells (n=112). No significant correlation was found to exist (P=0.3019, R=-0.0984, R-squared=0.0097, Tables 24 and 25).

Comparison of Figures 3 and 5 provides clues as to why no significant correlation was found. Firstly, areas of high deer density shown in Figure 3 are concentrated in northern, northwestern and south-central portions of the study area. These portions have a very high occurrence of sq.km cells with predicted winter ranks of 1 or 2 (Figure 5).

Table 24: Covariances and correlations between predicted winter habitat suitability ranks (PWR) and over-winter deer density estimates for a stratified random sample of sq.km UTM cells.

Statistic	Variable	Variable: PWR	Variable: Deer Density (#/sq.km)
Covariance	PWR	0.48399	-0.45246
Covariance	Deer Dens	-0.45246	43.6704
Mean		1.58786	4.99
Std Deviation		0.69569	6.60836
N		112	112
Correlation	PWR	1	-0.09842
Correlation	Deer Dens	-0.09842	1

Table 25: Analysis of variance and regression statistics for the simple linear regression of predicted winter habitat suitability rank (PWR) on over-winter deer density for a stratified random sample of sq.km UTM cells.

ANALYSIS OF VARIANCE

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE	PROB>F
Model	1	46.95019	46.95019	1.076	0.3019
Error	110	4800.46741	43.64061		
C Total	111	4847.41760			

ROOT MSE	6.60610	R-SQUARE	0.0097
DEP MEAN	4.99	ADJ R-SQ	0.0007
C.V.	132.3869		

PARAMETER ESTIMATES

VARIABLE	DF	PARAMETER ESTIMATE	STANDARD ERROR	T FOR H0: PARAMETER=0	PROB>|T|
INTERCEPT	1	6.47440	1.56133	4.147	0.0001
PWR	1	-0.93484	0.90129	-1.037	0.3019

Secondly, cells of rank 1 or 2 are also common in many areas of low deer density such as the southeastern corner of the study area. In other words, winter deer concentrations generally occurred in areas of good or optimal predicted rank, but many cells of rank 1 or 2 did not have high densities of deer in winter 1981-82. The latter phenomenon seems to have eroded any correlation that might have existed in the northern, northwestern and south-central areas, to the point where there was no significant correlation across the study area.

The winter concentration of deer in northern, northwestern and south-central portions of the study area was documented in 1980 and 1982 (Darby, 1980; Darby and Munn, 1982), but has not been specifically monitored by aerial survey since then. However, late fall movements of deer into these areas is known to be a common phenomenon in the study area. It is also known from observations by OMNR staff and unpublished mortality data that deer disperse themselves more evenly throughout the study area in summer.

Another possible reason for there being no significant correlation in Test 3 is inability of the MSS imagery to distinguish conifer species suitable as winter shelter such as jack pine, red pine, balsam, white spruce and cedar from conifer species generally unsuitable such as black spruce and larch. Certainly, at the time of programming it was recognized that trying to distinguish black spruce from cedar was beyond limitations of MSS technology; that is why one of the lowland conifer sub-themes is 'lowland conifer/cedar' (Appendix 1). However, all upland conifer species provide suitable winter shelter, whereas extensive larch and black spruce lowlands do not; hence the reasoning between trying to separate lowland and upland conifer during the supervised classification. It appears this attempt failed in part because of considerable overlap between two conifer training sub-themes, 'high density treed bog' and 'upland conifer' (Appendix 1). Confusion between the final lowland and upland conifer themes of the multi-date map was obvious in Table 12.

In order to assess the amount of Test 3 correlation reduction caused by this factor, UTM cells in which conifer stands were dominated by black spruce or larch were removed from the Test 3 data set. A second correlation was performed on the revised dataset (n=78). Although the R value increased from -0.0984 to -0.1649 there still was no significant correlation (R-squared=0.0272, P=0.3019) (Tables 26 and 27).

Table 26: Covariances and correlations between predicted winter habitat suitability ranks (PWR) and over-winter deer density estimates, for the revised sample of sq.km UTM cells, after cells with black spruce and larch-dominated forest stands were removed.

Statistic	Variable	Variable PWR	 Deer Density (#/sq.km)
Covariance	PWR	0.53573	-0.88419
Covariance	Deer Dens	-0.88419	53.695
Mean		1.66718	5.57769
Std Deviation		0.73194	7.32768
N		78	78
Correlation	PWR	1	-0.16486
Correlation	Deer Dens	-0.16486	1

Table 27: Analysis of variance and regression statistics for the simple linear regression of predicted winter habitat suitability rank (PWR) on over-winter deer density for the revised sample of sq.km UTM cells, after cells with black spruce and larch-dominated forest stands were removed.

ANALYSIS OF VARIANCE

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE	PROB>F
Model	1	112.36661	112.36661	2.123	0.1492
Error	76	4022.14578	52.92297		
C Total	77	4134.51238			

ROOT MSE	7.2748	R-SQUARE	0.0272
DEP MEAN	5.5777	ADJ R-SQ	0.0144
C.V.	130.427		

PARAMETER ESTIMATES

VARIABLE	DF	PARAMETER ESTIMATE	STANDARD ERROR	T FOR H0: PARAMETER=0	PROB>|T|
INTERCEPT	1	8.32928	2.06020	4.043	0.0001
PWR	1	-1.65044	1.13267	-1.457	0.1492

6.0 DISCUSSION

The study objectives were to predict habitat suitability for white-tailed deer on an ordinate scale for sq.km cells of the study area, and to test the accuracy of such predictions. The hypothesis was: predictions of habitat suitability derived from an MSS thematic map of white-tailed deer habitat of minimum 75% accuracy, are significantly ($P<0.05$) correlated with independent measures of habitat mosaic suitability, deer forage, cover and site characteristics.

The multi-date thematic map achieved an overall unbiased accuracy of 72.6 % with 10 habitat themes, and 77.0 % after reducing the number of themes to eight. While the reduction imposed some limitations on management application of the map, the classification was still meaningful for habitat evaluation. Hence the hypothesis requirement of minimum 75 % map accuracy was considered to be achieved.

The overall unbiased accuracy of 77.0% for the modified multi-date map took into account both errors of omission and commission and was corrected for differential visibility bias according to the methods of Card (1982). These refinements inherently reduced the final estimate of map accuracy. Many reports of thematic map accuracy in the literature are based on errors of omission or commission only, without correction for visibility bias (Walsh, 1980; Mayer and Fox, 1981; Bowes et al., 1984; Ormsby and Lunetta, 1987; Hopkins et al., 1988). If accuracy of the modified multi-date map had been based on errors of omission only, with no correction for visibility bias, estimated average accuracy would have been 81.1% (nii/n.i, calculated from Table 14).

Only two applications of satellite imagery to evaluating white-tailed deer habitat were found in the scientific literature (Boyd et al., 1981; Ormsby and Lunetta, 1987). Thematic map accuracy from this study is better than the 73% accuracy achieved with six themes and TM imagery by Ormsby and Lunetta. Boyd et al. did not report accuracy of their MSS thematic map.

The SAS computer program for generating predicted habitat suitability ranks performed well from a technical viewpoint, and SAS is recommended as a suitable programming language for this purpose in a management context. The use of arrays to display predicted ranks in map format with accompanying printouts of theme ranks and predictor variable data (CATPROP and EI) is also recommended. Changes recommended for program output are:

(1) predicted habitat suitability ranks should be generated as numbers to two decimal places. The use of an ordinate scale from 0.00 (unsatisfactory) to 1.00 (optimal) should be used (cf. Short, 1986). This will cause arrays (maps) of predicted ranks to be physically wider, necessitating subdivision of data files for printing on conventional micro-computers, but 'continuous' ranks are correlated much better with 'truth' than integer ranks.

(2) Cell entries of the array (map) of suitability ranks should be printed in a contour arrangement of print boldness, so that cells of good to optimal suitability are highlighted in the array.

(3) Determination of the edge index (EI) value should be computerized.

(4) Consideration should be given to incorporating a satellite-sensed or GIS measure of relief (topographical contours) in predicting habitat suitability. Relief adds diversity to deer habitat and improves it (Halls, 1984). Deer also favour south-facing slopes in winter because they have lower snow depths and more browse than north-facing slopes (Table 4).

Test 1 showed a highly significant correlation between predicted year-round and Test 1 ranks (P=0.0001), when ranks were generated to two decimal places: 61.6% of the variability in predicted ranks was explained by 'true' differences in suitability of the mosaic of important habitat types, based on descriptions of optimal conditions in the scientific literature (Tables 8 and 21). This result required acceptance of the first part of the study hypothesis.

A suitable mosaic of desirable habitat types (Table 8) with a high degree of edge, or interface between types, is necessary for an area to have potential as good white-tailed deer habitat (Tables 4 and 5). The methods used in generating predicted ranks are basically consistent with this requirement, but they placed equal emphasis on the relative importance of each 'theme rank'. Theme ranks were averaged and then added to the edge index value (-1,0,+1) to obtain predicted rank for a sq.km cell. In reality, simple averaging of theme ranks may not reflect the relative importance of different habitat types to white-tailed deer. Information in the literature, however, was not considered adequate to weight themes by relative importance.

Edge index was given a high degree of influence over predicted rank. This was an arbitrary decision based on best judgement, because the literature did not provide sufficient information on the importance of edge relative to proportions of important habitat types. However, only three EI values were possible, -1, 0 and +1. This did not allow for a continuous gradient of EI values which may have slightly reduced the correlation.

Test 2 showed a highly significant canonical correlation between predicted and Test 2 habitat ranks (P=0.0001, R=0.784): 61.5 % of the variability in predicted ranks was explained by real differences in the diversity, abundance and suitability of preferred foods, cover and site characteristics as determined by ground sampling (Table 23, Appendix 10). This result requires acceptance of the second part of the study hypothesis.

Test 2 results (Table 23) also showed that correlation of the predicted ranks was best with 'mean number of important browse species per plot' (R=-0.6629), 'number of changes in dominant tree species per sq.km sampled' (R=-0.6143), and 'mean number of important herbaceous forage species per plot' (R=-0.5569). This is a very important fact. It means that ranks predicted from reflected light from the top of the forest canopy correlated best with measures of diversity of understory food and dominant tree species. These are factors directly important to deer. The white-tailed deer is a creature of the forest edge, an early-successional species that thrives on habitat diversity (Halls, 1984).

Other substantial inverse correlations were with 'mean stand height per plot', 'number of changes in habitat theme per sq.km sampled', 'mean total basal area per plot' and 'mean soil fertility per plot'. These correlations are important but not as easily understood as the first three.

Mean stand height per plot (R=-0.5555) was mean height of the dominant tree species per plot in meters. One would expect this to be inversely correlated with predicted rank to a point, because as stand height increases from 0 to 2m, more browse is available to deer. An increase to 10m still improves habitat because this is early successional forest providing food and escape benefits (Table 5). Further increase implies better cover but less food. Eventually as mean stand height continues to increase, the correlation should worsen and become positive because of increasing forest maturity and homogeneity.

The number of theme changes per sq.km sampled (NTHEME, Table 23) had an R value of -0.5457. This variable represents a ground measure of habitat diversity that is independent of predicted rank. The fact that it had a fairly strong inverse correlation with predicted rank is important since it supports relevance of the predicted ranks to deer. It is a comparison, however, that is not completely independent from Test 1. One might argue that NTHEME should have been excluded from Test 2. However, it did not have an overriding influence on the Test 2 results.

Mean total basal area per plot had an R=-0.4394. Increasing tree density has benefit for deer to a point. For example, optimal conifer crown closure is 60-80% for winter habitat (Table 4). Above this percentage crown closure is so dense it restricts growth of understory browse (Euler and Thurston, 1980).

Mean soil fertility (MFERT) had an R=-0.4383. This is an interesting correlation because soil fertility was measured on an index of site classes from 1 to 3 based on growth rate of the dominant tree species on the plot (Plonski, 1974). Hence, high fertility was represented by site class 1. At first glance, one would expect fertility to be positively, not negatively, correlated with predicted rank. However, McCaffery and Creed (1969) found that forests averaged five times more meadow-type openings on sandy infertile soils in Wisconsin than forests on fertile loams. The forests on sandy soils also supported high densities of deer. This was because tree density and vegetation type were highly variable due to soil and soil moisture variations. Sandy till, infertile soils and rock outcrops are found in northern and northeastern portions of my study area. These probably have a beneficial effect on deer habitat by increasing diversity, especially because relief is more pronounced there as well. The inverse correlation of MFERT with predicted rank is consistent with this reasoning.

The remaining variables in Table 23 had weak inverse correlations. Notable among these were 'mean stand age per plot' (R=-0.3319), mean browse density per plot' (R=-0.3241), 'mean suitable conifer basal area per plot' (R=-0.2351), 'mean conifer crown closure per plot' (R=-0.1556) and 'mean herbaceous forage density per plot' (R=-0.1320). Mean stand age is another variable that would be expected to increasingly benefit deer as its value increased from zero, to a point, and thus be inversely correlated with predicted rank. This point would be the age at which the forest reaches maturity; beyond that age, value for deer would start to decrease.

The inverse correlations for mean browse density and herbaceous forage density appear surprisingly weak; diversity of forage was more strongly correlated with predicted rank. This suggests that diversity of forage is more strongly correlated with measurements of reflected light from the top of the forest canopy than forage abundance, a relationship that appears logical.

The inverse correlation of conifer variables with predicted rank is weak for two reasons: (1) the fact that increase in suitable conifer basal area and conifer crown closure are only beneficial to the point of 65 sq.m/ha and 80% respectively (Table 4); and the fact that optimum year-round habitat should have only 10-30% of the area in mature conifer stands (Table 8). With such a low percentage, and equal influence of theme ranks, one can't expect a strong correlation with predicted year-round rank.

For all Test 2 summary variables that increased benefit to deer as their value increased to a point, it must be recognized that beyond such point the positive nature of the correlation would counteract the otherwise inverse relationship with predicted rank. This would have the effect of reducing the maximum attainable strength of the inverse correlation to something less than -1.000 and hence, the maximum attainable strength of the squared canonical correlation. This is likely one reason the Test 2 result was not higher than 61.5%. Another may be the fact that EI had only three possible values and was not a 'continuous' variable.

Given the considerations mentioned above, results of Test 2 are encouraging. This is because field measurements of forage, cover and site explained the majority of variability in predicted ranks, while some artifacts in the Test 2 summary data were limiting correlation.

The Test 2 summary data had a higher canonical correlation with predicted ranks (CC=0.7844) than with Test1 ranks (CC=0.7355), and the highest PYRR-Test2 correlations were with measures of diversity of food and forest stands. This, coupled with the fact that variability of the predicted rank dataset was 22.7% greater than that of the T1YR dataset (Table 20), means the thematic map better reflected diversity of the habitat than my interpretation of airphotos. This may have a bearing on the Test 1 results. The Test 1 R-squared value may not have been higher than 0.616 because my interpretation of airphotos tended to 'lump' habitats more than the spectral data.

Successful completion of Test 3 was not a prerequisite for hypothesis acceptance according to the study objective (Sec. 1.0). Given this, Test 3 showed no significant correlation between predicted winter habitat rank and over-winter deer density (P=0.3019, R=-0.098). However, many factors can affect winter deer distribution, such as snow depth, winter severity, predators, human activities, artificial food sources, and topography. Clearly, factors other than winter habitat rank were operative here.

As mentioned in Sec. 5.6, deer in the study area are known to concentrate in winter in northern, northwestern and south-central portions of the study area. This was consistent with a high prevalence of cells with predicted rank 1 or 2 in those portions of the study area, but not in other portions. The movement of deer to winter concentration areas does not mean that the predicted winter ranks are without value.

The tendency for northern white-tailed deer to make directed movements to winter concentration areas with suitable conifer shelter, and disperse in spring, has been well documented (Rongstad and Tester, 1969; Verme and Ozoga, 1971; Ozoga and Gysel, 1972; Verme, 1973; Drolet, 1976; Nelson and Mech, 1981). Many reasons for this behaviour have been discussed in the scientific literature, but the two most important are (Schmidt and Gilbert, 1978:328; Halls, 1984:199 & 399):

(1) Conifer shelter reduces snow depth and provides thermal and escape cover.

(2) There is safety in numbers through: increased collective vigilance for predators decreasing individual vigilance time, trailing, use of other deer as escape cover, and a greater ratio of deer to territorial predators.

These factors provide advantages to deer through improved predator escape and minimization of energy expenditures (Ozoga and Gysel, 1972; Halls, 1984). Another factor relevant to the study area is that agricultural lands and human activity (eg. roads, dogs, snowmobiles) are more commonplace in the southern than northern half of the study area (Plate 2).

Despite the Test 3 results, I believe the predicted ranks are measuring habitat suitability for deer at a minimum level of 61.5% reliability. The scientific literature shows deer prefer the optimal conditions described in Tables 4 and 5. Assuming that deer habitat preferences can be used as indicators of habitat suitability, the predicted ranks reflect suitability. The literature also confirms that potential for deer population growth improves as habitat suitability improves, ie. food, water and cover abundance, diversity and proximity (Dasmann, 1971; Schmidt and Gilbert, 1978; McCullough, 1979; Halls, 1984). This phenomenon occurs primarily because of the relationship of nutritional plane to productivity (Schmidt and Gilbert, 1978:344), and of predator avoidance and escape behaviour to mortality (McCullough, 1979; Halls, 1984).

The above discussion indicates that MSS technology is very close to being sufficiently accurate for evaluating white-tailed deer habitat in an applied management context, for the following reasons:

(1) The mean predicted year-round rank (2.274) was very close to the mean Test1 rank (2.338).

(2) Both Tests 1 and 2 showed that a minimum 61.5% of the variability in predicted year-round ranks was explained by the respective dataset.

(3) PYRR-Test2 correlations were highest with measures of diversity of deer forage and forest stands.

(4) Artifacts in the Test2 summary data caused the maximum attainable canonical correlation for Test 2 to be something less than 100%.

(5) Test 1 and 2 results show that measurements of reflected light from the forest canopy (predicted ranks) were better correlated with diversity of food, cover and site than my interpretation of airphotos.

(6) In winter 1982, deer concentrated in portions of the study area with high prevalence of predicted winter ranks of 1 and 2.

Nevertheless, I believe predicted ranks should attain a minimum R-squared value of 0.75 with 'truth' to be acceptable for management application. Improvements in thematic map accuracy and the methods for testing against 'truth' should allow this. In order to facilitate these improvements, it is important to consider the sources of error that reduced accuracy of the thematic map, and of the predicted ranks.

The largest sources of error appeared to be the definition of certain themes and limitations of MSS technology. In the multi-date map, the lowland conifer, upland conifer, unimproved pasture and developed agricultural themes were all separated for reasons relating to deer habitat use. For example, all upland coniferous species in the study area (jack, red and white pine, balsam fir and white spruce) provide suitable conifer shelter for deer. With the exception of cedar, lowland conifer in the study area are less suitable because they generally comprise larch and black spruce-dominated muskeg with an understory of labrador tea (Ledum groenlandicum) on sphagnum moss (Sphagnum spp.) as an understory. These larch and black spruce muskegs do not provide low snow depths in winter, but they can provide some thermal and escape cover for deer, especially in summer. Cedar, on the other hand, is an important lowland species for deer, providing low snow depths and serving as important food and cover (Smith and Borczon, 1981; Halls, 1984).

With regard to the unimproved pasture and developed agricultural themes, detailed evaluation of white-tailed deer habitat should include an inventory of small (0.2 to 4.0 ha) meadow-type openings in the forest (McCaffery and Creed, 1969; Euler, 1979; OMNR, 1984a). These are very important feeding areas in autumn when deer are building up fat reserves, and in early spring when they are recovering from the nadir of their physiological cycle (McCaffery and Creed, 1969). Snow melts earlier in meadows, fields and along roadsides than in the forest, exposing green forbs that survived winter under the snow.

Accuracy assessment showed the most severe confusion between multi-date themes was between lowland and upland conifer, and between unimproved pasture and developed agricultural land (Table 12). In programming for classification of the multi-date map it would have been most desirable to separate coniferous species into upland conifer, cedar and lowland conifer. As mentioned in Sec. 5.6, however, spectral separation of cedar from black spruce and larch was considered to be beyond MSS capabilities. Hence only two coniferous themes were classified: upland and lowland conifer. Much of the subsequent confusion between these themes seems due to spectral similarity between the 'high density treed bog' and 'upland conifer' sub-themes (Appendix 1). This inability of MSS imagery to differentiate between coniferous species is a problem that needs to be overcome to make full use of satellite imagery for purposes of habitat evaluation for northern white-tailed deer.

Spectral signatures for training areas for unimproved pasture and the 'DAL-blue mottle' sub-theme (Appendix 1) were also similar. In Sec. 5.2, I mentioned the hay field example as a biophysical gradient between the UP and DAL themes. Active pastures are at times another example. It is desirable to separate UP and DAL themes if possible, but failure to differentiate them is not as serious for evaluating deer habitat as the conifer problem. Agricultural lands can provide food for deer, and UP can be evaluated as a sub-theme of DAL. The important factors determining value of agricultural lands to deer are proportion of total area, edge index and crop. In the study area, most field margins and many crops provided food for deer. The modified multi-date map identified unimproved pasture and developed agricultural land as belonging to the pooled UP&DAL theme for areas as small as one pixel (56 x 79m, or 0.44 ha) with an unbiased accuracy of 81.3% for errors of omission and 61% for errors of commission (data not reported herein).

Some confusion existed among remaining themes of the modified multi-date map (Table 14), but other sources of error may have been involved. For example, there were substantial commission errors between the pooled 'UP&DAL' theme and 'early successional hardwoods and shrubs'. Some of this error may be misclassification due to theme definition/technological limitations, but some may also be due to changes in the habitat between: the first date of imagery, June 25, 1980; the second date of imagery, May 8, 1983; and the date of airphotos, summer 1982. Some land clearing and cultivation of old pastures did occur during this time. Not all were corrected during editing of the multi-date map. In other cases, error may be due to spectral differences approaching the noise level, for example the 4% error of commission between the 'water' and 'open wetland' themes in Table 14.

Geometric and radiometric residual errors and edge misclassification seemed to be minor factors in my study, but they did contribute to reducing both thematic map accuracy and Test 1 and 2 correlations (data not reported herein). For example, in north-central portions of the study area some difficulty was observed in aligning imagery and airphotos according to the 10 x 10km UTM grid on the thematic map. This difficulty seemed to be due to distortion of the image resulting from intensity interpolation and resampling during the geometric rectification process (Jensen, 1986). During map accuracy assessment and collection of Test 1 and 2 data, this problem was corrected as much as possible by re-aligning a 10 x 10 km grid overlay manually on the thematic map. However, some misalignment may have persisted.

Certainly, rectification and grid registration problems are ones that constitute a potential source of error in every management application of satellite imagery. They may be due to image distortion due to intensity interpolation, resampling, registering a UTM grid to the thematic map, or registering an image to GIS coordinates. Every precaution should be taken to ensure minimal distortion and accurate alignment.

With better methods and technology, it is likely that higher accuracy can be achieved for thematic maps and predicted ranks. Methods for improving thematic map accuracy may currently exist. Some improvement may have been possible in this study. For example, overlap problems with spectral signatures for training sub-themes may have been avoidable by more aggressive rejection and replacement of training areas, or by waiting for two dates of haze-free imagery so that eight separate bands could be used instead of six. Individual spectral band selection or band ratioing may have helped classify certain sub-themes in areas of shadow (e.g. under clouds).

The more expensive TM imagery may achieve higher map accuracy, having seven bands and 30 x 30m resolution, but it wasn't achieved in Ormsby and Lunetta's (1987) study. TM or SPOT imagery may offer greater potential for individual band selection or band ratioing to solve classification problems.

Hopkins et al. (1988) concluded that TM technology has better potential for differentiation of forest themes than MSS data (see Sec. 2.1.4). However, it was evident from their results that TM application to wildlife habitat evaluation still needs considerable refinement. Satterwhite et al. (1984) pointed out that different land-use classes often fall into the same spectral class, and refinement cannot be readily achieved with Landsat imagery. They suggested plant phenological characteristics and plant habitat requirements be incorporated into the digital image analysis and evaluation process. The use of soil and landform maps may help in this regard.

Assuming the necessary improvements can be made, how could a deer habitat evaluation system using satellite data be employed in a forest management context? One possible scenario is to do a computer search on the file of predicted year-round ranks, for those square kilometers having a poor rank due to a low proportion of early successional forest or openings. Such sites could be recommended for cutting in timber management plans to improve deer habitat in future. Such an approach uses timber management activities as a deer habitat management tool.

The thematic map and associated array of deer habitat ranks could also be used as an information source in planning forest access road location to maximize benefits for deer management, and minimize future problems. For example, one could avoid dissecting areas of optimal winter habitat, and re-direct roads to mature forest that requires cutting for deer habitat improvement. The thematic map itself has a variety of potential uses because of its generalized vegetation themes. Examples are: waterfowl management, planning access for wildlife viewing or hunting, identification of potential wildlife viewing sites, and planning emergency deer feeding/trail breaking projects. There are many potential ways to use satellite imagery for cost-effective wildlife management, especially if it is combined with GIS data.

In summary, this study developed a thematic map of deer habitat of 77% accuracy from MSS imagery. It developed a computer program that predicted habitat suitability ranks from the thematic map for winter, summer and year-round periods for each sq.km of the study area. It showed that at least 61.6% of the variability in predicted year-round ranks was explained by 'true' suitability of the habitat mosaic, and at least 61.5% was explained by ground measurements of deer food, cover and site characteristics. Correlations were highest with ground measures of diversity of deer browse and herbaceous forage, and forest stand.

If improvements in methods and satellite technology can be achieved to attain R-squared values of at least 0.75 for Tests 1 and 2, I believe the predicted ranks would have acceptable accuracy for management application. The system developed in this study would then comprise a cost-effective method of evaluating deer habitat over wide areas. It could be used in other areas of the Great Lakes-St. Lawrence Forest in Ontario and the northern lake States. Verification of acceptable map accuracy would be required in each area, but the predicted ranks would not have to be tested. The system would also allow frequent, inexpensive updates, and temporal or between-area comparisons. The deer manager using such a system would be well on his or her way to enacting a desirable and sophisticated management strategy for white-tailed deer on northern range.

7.0 LITERATURE CITED

AHERN, F.J. 1983. New Landsat MSS enhancements. Remote Sensing News Briefs; Energy, Mines and Resources Canada, Ottawa 14 pp.

AHERN, F.J., D.M. BENNETT, F.E. GUERTIN, K.P.B. THOMSON and G. FEDOSEJEVES. 1982. An automated method for producing reflectance-enhanced Landsat images. Proceedings 8th International Symposium on Machine Processing of Remotely Sensed Data, Purdue University. pp.328-336.

ALDOUS, S.E. and C.F. SMITH. 1938. Food habits of Minnesota deer as determined by stomach analysis. Transactions North American Wildlife Conference 3:756-767.

ALFOLDII, T.T. 1978. Introduction to digital images and digital analysis techniques: a basic course for the appreciation of digital analysis of remotely sensed multispectral data. Canada Department of Energy, Mines and Resources, Canada Centre for Remote Sensing Technical Note 78-1. 10 pp.

ANDERSON, A.E., D.E. MEDIN and D.C. BOWDEN. 1972. Indices of carcass fat in a Colorado mule deer popultion. Journal of Wildlife Management 36:579-594.

ANDERSON, J.R., E.E. HARDY, J.T. ROACH and R.E. WITMER. 1976. A land use and landcover classification system for use with remote sensor data. United States Geological Survey Professional Paper 964. 28 pp.

ARMSTRONG, E., D. EULER and G. RACEY. 1983a. White-tailed deer habitat and cottage development in central Ontario. Journal of Wildlife Management 47(3):605-612.

ARMSTRONG, E., D.EULER and G. RACEY. 1983b. Winter bed-site selection by white-tailed deer in central Ontario. Journal of Wildlife Mangement 47(3):880-884.

ARONOFF, S. 1982b. Classification accuracy - a user approach. Photogrammetric Engineering and Remote Sensing 48(8): 1299-1307.

ARONOFF, S. 1982a. The map accuracy report: a user's view. Photogrammetric Engineering and Remote Sensing 48(8): 1309-1312.

ASHERIN, D.A., H.L. SHORT and J.E. RUELLE. 1979. Regional evaluation of wildlife habitat quality using rapid assessment methodologies. Transactions North American Wildlife and Natural Resources Conference 44:404-425.

BARTMANN, R.M. 1982. Evaluation of winter food choices by tame mule deer. Journal of Wildlife Management 46(3):807-812.

BARTMANN, R.M., and L.H. CARPENTER. 1982. Effects of foraging experience on food selectivity of tame mule deer. Journal of Wildlife Management 46(3):813-818.

BEAUBIEN, J. 1979. Forest type mapping from Landsat digital data. Photogrammetric Engineering and Remote Sensing 45(8): 1135-1144.

BEAUBIEN, J. 1980. Forest typing from digitized Landsat images in Quebec. Pp. 53-58 In Remote Sensing Symposium, Canada Department of the Environment, Canadian Forest Service, Great Lakes Forest Research Centre, Sault Saint Marie, Ontario. 189 pp.

BENNETT, C.L. Jr., E.E. LANGENAU, Jr., G.E. BURGOYNE, Jr., J.L. COOK, J.P. DUVENDECK, E.M. HARGER, R.J. MORAN and L.G. VISSER. 1980. Experimental management of Michigan's deer habitat. Transactions of the North American Wildlife and Natural Resource Conference 45:288-306.

BERGERUD, A.T. and L. RUSSELL. 1964. Evaluation of rumen analysis for Newfoundland caribou. Journal of Wildlife Management 28:809-814.

BOWLES, L., R. DIXON and B. KNUDSEN. 1984. Moose habitat analysis in north-central Manitoba from Landsat data. Manitoba Department Natural Resources, Surveys and Mapping, unpublished report, Winnipeg, Manitoba. 26 pp.

BOYCE, S.G. 1977. Management of eastern forests for multiple benefits (DYNAST-MB). United States Department of Agriculture, Forest Service Research Paper SE-168, Southeastern Forest Experimental Station, Asheville, North Carolina. 116 pp.

BOYCE, S.G. 1978. Management of forests for timber and related benefits (DYNAST-TM). United States Department of Agriculture, Forest Service Research Paper SE-184, Southeastern Forest Experimental Station, Asheville, North Carolina. 140 pp.

BOYD, M., W. HALL, G. LANGFORD and A. COOK. 1981. Integration of Landsat imagery into a program for aerial surveying of deer populations in Alberta. Pp. 222-227 In Proceedings of the Seventh Canadian Symposium on Remote Sensing, Winnipeg, Manitoba.

BRAMBLE, W.C. and W.R. BYRNES. 1979. Evaluation of the wildlife habitat values of rights-of-way. Journal of Wildlife Management 43(30):642-649.

BROOKS, R.T. and C.T. SCOTT. 1983. Quantifying land-use edge from aerial photographs. Wildlife Society Bulletin 11(4):389-391.

BYELICH, J.D., L.L. COOK and R.I. BLOUCH. 1972. Management for deer. Pp 120-125 In Proceedings of the Aspen Symposium, North Central Forest Experimental Station.

BYRNE, G.F. P.F. CRAPPER and K.K. MAYO. 1980. Monitoring land cover changes by principal component analysis of multi-temporal Landsat data. Remote Sensing of the Environment 10:175-184.

CAMPBELL, J.B. 1987. Introduction to remote sensing. The Guilford Press, New York. 551 pp.

CANNON, R.W., F.L. KNOPF and L.R. PETTINGER. 1982. Use of Landsat data to evaluate lesser prairie chicken habitats in western Oklahoma. Journal of Wilflife Management 46(4): 915-922.

CARD, D.H. 1982. Using known map category marginal frequencies to improve estimates of thematic map accuracy. Photogrammetric Engineering and Remote Sensing 48(3): 431-439.

CAUGHLEY, G. 1979. What is this thing called carrying capacity? Pp 2-8 In M.S. Boyce and L.D. Hayden-Wing (eds.). North American Elk:Ecology, Behavior and Management. University of Wyoming Press, Laramie, Wyoming. 294 pp.

CHAMRAD, A.D. andT.W. BOX. 1968. Food habits of white-tailed deer in south Texas. Journal of Range Management 21:158-164.

COBLENTZ, B.E. 1970. Food habits of the George Reserve deer. Journal of Wildlife Management 34:535-540.

COLWELL, J.E., D.S. GILMER, E.A. WORK, Jr., D.L. REBEL and N.E.G. ROLLER. 1978. Use of Landsat data to assess waterfowl habitat quality. Environmental Research Institute of Michigan Report 120000-15-F, Ann Arbor, Michigan. 83 pp.

COLWELL, R.N., D.S. SIMONETT and F.T. ULABY (eds.). 1983. Manual of remote sensing, second edition. Vol I. American Society of Photogrammetry, Falls Church, Virginia. 1232 pp.

CRAIGHEAD, J.J., J.S. SUMNER and G.B. SCAGGS. 1982. A definitive system for analysis of grizzly bear habitat and other wilderness resources utilizing LANDSAT multispectral imagery and computer technology. Wildlife-Wildlands Institute Monograph Number 1, University of Montana, Missoula, Montana. 279 pp.

CRAWFORD, H.S. 1982. Seasonal food selection and digestibility by tame white-tailed deer in central Maine. Journal of Wildlife Management 46(4):974-982.

DARBY, W.R. 1980. The 1980 deer population inventory and winter mortality survey of wildlife management unit 10, Fort Frances District. Ontario Ministry of Natural Resources unpublished report, Fort Frances, Ontario. 61 pp.

DARBY, W.R and D.F. MUNN. 1982. The 1982 deer population inventory and winter mortality survey of wildlife management unit 10, Fort Frances District. Ontario Ministry of Natural Resources unpublished report, Fort Frances District Report Series Number 1. 31 pp.

DASMANN, W. 1971. If deer are to survive. Stackpole Books, Harrisburg, Pennsylvania. 128 pp.

DAVENPORT, L.A., D.F. SWITZENBERG, R.C. VAN ETTEN and W.D. BURNETT. 1953. A study of deeryard carrying capacity by controlled browsing. Transactions of the North American Wildlife Conference 18:581-596.

DIXON, R.J. and L. HORN. 1981. Digital colour enhancement of Landsat data for mapping vegetation of barrenground caribou winter range in northern Manitoba. Pp. 197-205 In Proceedings of the Seventh Canadian Symposium on Remote Sensing.

DODGE, A.G. and E.S. BRYANT. 1976. Forest mapping with satellite data. Journal of Forestry 74(8):526-531.

DRAWE, D.L. 1968. Mid-summer diet of deer on the Welder Wildlife Refuge. Journal of Range Management 21:164-166.

DROLET, C.A. 1976. Distribution and movements of white-tailed deer in southern New Brunswick in relation to environmental factors. Canadian Field-Naturalist 90:123-136.

DROLET, C.A. 1978. Use of forest clear-cuts by white-tailed deer in southern New Brunswick and central Nova Scotia. Canadian Field-Naturalist 92(3):275-282.

DUNKENSON, R.L. 1955. Deer range appraisal for the Missouri Ozarks. Journal of Wildlife Management 19:358-364.

EDWARDS, R.Y. and C.D. FOWLE. 1955. The concept of carrying capacity. Transactions of the North American Wildlife Conference 20:589-602.

ELLIS, J.A., J.N. BURROUGHS, M.J. ARMBRUSTER, D.L. HALLETT, P.A. KORTE and T.S. BASKETT. 1978. Results of testing four methods of habitat evaluation. Report to the Project Impact Evaluation Team, Division of Ecological Services, United States Fish and Wildlife Service, Fort Collins, Colorado. 92 pp.

ELLIS, J.A., J.N. BURROUGHS, M.J. ARMBRUSTER, D.L. HALLETT, P.A. KORTE and T.S. BASKETT. 1979. Appraising four field methods of terrestrial habitat evaluation. Transactions of the North American Wildlife and Natural Resources Conference 44:369-379.

ENVIRONMENT CANADA. 1982. Canadian climate normals Volume 6, 1951-1980. Environment Canada, Ottawa, Ontario. 276 pp.

EULER, D. 1979. Vegetation management for wildlife in Ontario. Ontario Ministry of Natural Resources, Toronto, Ontario. 61 pp.

EULER, D. and L. THURSTON. 1980. Characteristics of hemlock stands related to deer use in east-central Ontario. Journal of Applied Ecology 17:1-6.

FERNALD, M.L. 1970. Gray's manual of botany eighth edition. D.Van Nostrand Company, New York, New York. 1632 pp.

FISHER, L.T., F.L. SCARPACE and R.G. THOMSEN. 1979. Multi-date Landsat lake quality monitoring program. Photogrammetric Engineering and Remote Sensing 45(4): 519-527.

FISHERIES AND ENVIRONMENT CANADA. 1978. Hydrological atlas of Canada. Supply and Services Canada, Ottawa, Ontario. 34 pp.

FITZPATRICK-LINS, K. 1981. Comparison of sampling procedures and data analysis for a land-use and land-cover map. Photogrammetric Engineering and Remote Sensing 47(3): 343-351.

FLOOD, B.S., M.E. SANGSTER, R.D. SPARROWE and T.S. BASKETT. 1977. A handbook for habitat evaluation procedures. United States Department of the Interior, Fish and Wildlife Service Resource Publication 132, Washington, D.C. 77 pp.

FOX III, L., K.E. MAYER and A.R. FORBES. 1983. Classification of forest resources with Landsat data. Journal of Forestry 81(5):283-287.

GARROD, R.C., M.W. SHOESMITH and J.M. STEWART. 1981. Rumen analysis of white-tailed deer, elk and moose killed by hunters and vehicle collisions in Manitoba 1975-1978. Manitoba Department of Natural Resources, Wildlife Branch Biological Services MS report Number 81-5. 45 pp.

GATES, J.E. and D.M. HARMAN. 1980. White-tailed deer wintering areas in a hemlock-northern hardwood forest. Canadian Field-Naturalist 94:259-268.

GILL, J.D. 1957a. Review of deer yard management 1956. Game Division Bulletin 5. Augusta: Maine Department of Inland Fish and Game. 61 pp.

GILL, J.D. 1957b. Effects of pulpwood cutting practices on deer. Pp. 137-146 In Proceedings of the Society of American Foresters 1957.

GINEVAN, M.E. 1979. Testing land-use map accuracy: another look. Photogrammetric Engineering and Remote Sensing 45(10): 1371-1377.

GOLDBERG, M. and S.SHLEIN. 1976. Computer implementation of a four-dimensional clustering algorithm. Canada Department of Energy, Mines and Resources, Canada Centre for Remote Sensing Research Report 76-2. 31 pp.

GOODENOUGH, D.G. 1979. The image analysis system (CIAS) at the Canada Centre for Remote Sensing. Canadaian Journal of Remote Sensing 5(1):3-17.

GYSEL, L.W. and L.J. LYON. 1980. Habitat analysis and evaluation. Pp. 305-327 In S.D. Schemnitz (ed.). Wildlife Management Techniques Manual, Fourth Edition: Revised. The Wildlife Society, Washington, D.C. 686 pp.

HALLS, L.K. (ed.). 1984. White-tailed deer ecology and management. Wildlife Management Institute, Stackpole, Harrisburg, Pennsylvania. 870 pp.

HALLETT, D.R. and M.A. ROED. Stratton area (NTS 52D/NE) District of Rainy River. Ontario Geological Survey, Northern Ontario Engineering Geology Terrain Study 52, Ontario Ministry of Natural Resources, Toronto, Ontario. 15 pp.

HAMERSTROM, F.N. and J. BLAKE. 1939. Winter movements and winter foods of white-tailed deer in central Wisconsin. Journal of Mammalogy 20(2):206-215.

HARPER, D. 1976. Eye in the sky - introduction to remote sensing. Canada Science Series, Multiscience Publications Ltd., Montreal, in association with Canada Department of Energy, Mines and Resources and Information Canada. 164 pp.

HAY, A.M. 1979. Sampling designs to test land-use map accuracy. Photogrammetric Engineering and Remote Sensing 45(4): 529-533.

HEALY, W.M. 1971. Forage preferences of tame deer in a northwest Pennsylvania clearcutting. Journal of Wildlife Management 35(4):717-722.

HEATH, G.R. 1974. ERTS data tested for forestry application. Photogrammetric Engineering and Remote Sensing 40(9): 1087-1091.

HEPBURN, R.L. 1968. Experimental management of mixed conifer swamps for deer and timber in eastern Ontario. Ontario Department of Lands and Forests, Section Report 96, Toronto, Ontario.

HOBBS, N.T., D.L. BAKER, J.E. ELLIS, D.M. SWIFT and R.A. GREEN. 1982. Energy and nitrogen-based estimates of elk winter-range carrying capacity. Journal of Wildlife Management 46(1):12-21.

HOLECHEK, J.L. and B. GROSS. 1982. Training needed for quantifying simulated diets from range plants. Journal of Range Management 35(5):644-647.

HOLECHEK, J.L., M. VAVRA and R.D. PIEPER. 1982. Botanical composition determination of range herbivore diets: a review. Journal of Range Management 35(3):309-315.

HOPKINS, P.F., A.L. MACLEAN and T.M. LILLESAND. 1988. Assessment of thematic mapper imagery for forestry applications under Lake States conditions. Photogrammetric Engineering and Remote Sensing 54(1):61-68.

HORN, L.N.G. 1981. Vegetation mapping in northern Manitoba with Landsat: preliminary assessment of barren-ground caribou wintering range. Master of Natural Resource Management Practicum, University of Manitoba, Winnipeg, Manitoba. 122 pp.

HUBERT, G.F., Jr., A. WOLF and G. POST. 1980. Food habits of a supplementally-fed captive herd of white-tailed deer. Journal of Wildlife Management 44(3):740-746.

HUFFAKER, C.B. and P.S. MESSENGER. 1964. The concept and significance of natural control. Pp. 74-117 In P. DeBach (ed.). Biological Control of Insect Pests and Weeds. Chapman and Hall Ltd., London.

HUOT, J. 1974. Winter habitat of white-tailed deer at Thirty-one Mile Lake, Quebec. Canadian Field-Naturalist 88:293-301.

JENSEN, J.R. 1986. Introductory digital image processing. Prentice-Hall, Englewood Cliffs, New Jersey. 379 pp.

JOHNSON, M.K., H. WOFFORD and H.A. PEARSON. 1983. Digestion and fragmentation: influence on herbivore diet analysis. Journal of Wildlife Management 47(3):877-879.

JOHNSTON, I.L. and P.J. HOWARTH. 1980. Digital enhancements for vegetation mapping in a subarctic environment. Pp. 405-410 In Proceedings of the Sixth Canadian Symposium on Remote Sensing.

KARNS, P.D. 1980. Winter - the grim reaper. Pp. 47-53 In Hine, R.L. and S. Nehls (eds.). White-tailed Deer Population Management in the North-Central States. Proceedings of the 1979 Symposium of the North Central Section of The Wildlife Society. 116 pp.

KEARNEY, S.R. and F.F. GILBERT. 1976. Habitat use by white-tailed deer and moose on sympatric range. Journal of Wildlife Management 40:645-657.

KIRBY, C.L., D. GOODENOUGH, D. DAY and P. VAN ECK. 1975. Landsat imagery for Banff and Jasper National Parks inventory and management. Pp. 207-225 In Proceedings of the Third Canadian Symposium on Remote Sensing.

KLEIN, D.R. 1970. Food selection by North American deer and their response to over-utilization of preferred plant species. Pp. 25-46 In A. Watson (ed.). Animal Populations in Relation to Their Food Resources. Proceedings of the British Ecological Society Symposium Number 10, 1969, Blackwell Scientific Publications, Oxford. 477 pp.

KOHN, B.E. and J.J. MOOTY. 1971. Summer habitat of white-tailed deer in north-central Minnesota. Journal of Wildlife Management 35:476-487.

KORSCHGEN, L.J. 1962. Foods of Missouri deer with some management implications. Journal of Wildlife Management 26:164-172.

KORSCHGEN, L.J. 1980. Procedures for food-habits analyses. Pp.113- 127 In S.D. Schemnitz (ed.). Widlife Management Techniques Manula, Fourth Edition: Revised. The Wildlife Society, Washington, D.C. 686 pp.

KORSCHGEN, L.J., W.R. PORATH and O. TORGERSON. 1980. Spring and summer foods of deer in the Missouri Ozarks. Journal of Wildlife Management 44:89-97.

KUCERA, E. 1976. Effects of winter conditions on the white-tailed deer of Delta Marsh, Manitoba. Canadian Journal of Zoology 54:1307-1313.

LANG, B.K. and J.E. GATES. 1985. Selection of sites for winter night beds by white-tailed deer in a hemlock-northern hardwood forest. The American Midland Naturalist 113 (2):245-254.

LANSING, J.C. and R.W. CLINE. 1975. The four and five band multispectral scanners for Landsat. Optical Engineering 14:312-322.

LA PERRIERE, A.J.L. III. 1976. Feasibility of caribou winter habitat analysis using satellite data. Ph.D. Thesis, University of Alaska, Fairbanks, Alaska. 181 pp.

LA PERRIERE, A.J.L., III, P.C. LENT, W.C. GASSOWAY and F.A. NODLER. 1980. Use of landsat data for moose habitat analysis in Alaska. Journal of Wildlife Management 44(4):881-887.

LEACH, H.R. 1956. Food habits of the Great Basin deer herds of California. California Fish and Game 42:243-308.

LEE, Y.J. 1977. Computer-assisted forest land calssification by means of several classification methods on the CCRS Image-100. Pp.37-46 In Proceedings of the Fourth Canadian Symposium on Remote Sensing.

LENT, P.C. and A.J. LA PERRIERE. 1974. Applications of ERTS imagery to the study of caribou movements and winter habitat. National Technical Information Survice, Final Report NASA Contract NAS521833. 50 pp.

LOTKA, A.J. 1925. Elements of physical biology. Williams and Wilkins, Baltimore, reprinted by Dover Publications, New Yory, New York. 1956. 460 pp.

MARKHAM, B.L. and J.L. BARKER. 1983. Spectral characterization of the Landsat 4 MSS sensors. Photogrammetric Engineering and Remote Sensing 49(6):811-833.

MAUTZ, W.W. 1978. Nutrition and carrying capacity. Pp. 321-348 In J.L. Schmidt and D.L. Gilbert (eds.). Big Game of North America. Stackpole, Harrisburg, Pennsylvania.

MAUTZ, W.W., H. SILVER, J.B. HOLTER, H.H. HAYES and W.E. URBAN. 1976. Digestibility and related nutritional data for seven northern deer browse species. Journal of Wildlife Management 40:630-638.

MAYER, .E. and L. FOX III. 1981. Identification of conifer species groupings from Landsat digital classifications. Photogrammetric Engineering and Remote Sensing 48(11): 1607-1614.

McCAFFERY, K.R., J.E. ASHBRENNER and J.C. MOULTON. 1981. Forest opening construction and impacts in northern Wisconsin. Wisconsin Department of Natural Resources Technical Bulletin Number 120. 40 pp.

McCAFFERY, K.R. and W.A. CREED. 1969. Significance of forest openings to deer in northern Wisconsin. Wisconsin Department of Natural Resources Technical Bulletin Number 44. 104 pp.

McCAFFERY, K.R., J. TRANETZKI and J. PIECHURA. 1974. Summer foods of deer in northern Wisconsin. Journal of Wildlife Management 38(2):215-219.

McCULLOUGH, D.R. 1979. The George Reserve deer herd - population ecology of a K-selected species. The University of Michigan Press, Ann Arbor, Michigan. 271 pp.

McGINNIS, D.F. and S.R. SCHNEIDER. 1978. Monitoring river ice break-up from space. Photogrammetric Engineering and Remote Sensing 44(1):57-68.

MEDIN, D.E. 1970. Stomach content analysis: collections from wild herbivores and birds. P. 133-145 In Range and Wildlife Habitat Evaluation - A Research Symposium. United States Department of Agriculture, Forest Service Miscellaneous Publication 1147. 220 pp.

MOEN, A.N. 1968. Energy exchange of white-tailed deer, western Minnesota. Ecology 49(4):676-682.

MOEN, A.N. 1973. Wildlife ecology - an analytical approach. W.H. Freeman and Company, San Francisco, California. 458 pp.

MOEN, A.N. 1976. Energy conservation by white-tailed deer in the winter. Ecology 57(1):192-198.

MOEN, A.N. 1978. Seasonal changes in heart rates, activity, metabolism and forage intake of white-tailed deer. Journal of Wildlife Management 42(4):715-738.

MOORE, G.C. and A.H. BOER. 1977. Forestry practices and deer habitat management. Deer Management Report 4, Fish and Wildlife Branch, New Brunswick Department of Natural Resources, Fredricton, New Brunswick. 52 pp.

MOOTY, J.J. 1976. Year-round food habits of white-tailed deer in northern Minnesota. Minnesota Department of Conservation, Wildlife Research Quarterly 36(1):11-36.

MOOTY, J.J., P.D. KARNS and T.K. FULLER. 1987. Habitat use and seasonal range size of white-tailed deer in northcentral Minnesota. Journal of Wildlife Management 51(3):644-648.

MURPHY, J. 1979. Format specifications for Canadian Landsat MSS system corrected computer compatible tape. Energy, Mines and Resources Canada, Canada Centre for Remote Sensing Research Report 79-2, Ottawa, Ontario. 71 pp.

NASA. 1982. Landsat 4. Landsat Data Users Notes 23:1-10., NASA United States Geological Survey, Eros Data Center, Sioux Falls, South Dakota.

NELSON, M.E. and L.D. MECH. 1981. Deer social organization and wolf predation in northeastern Minnesota. Wildlife Monograph Number 77. 53 pp.

NIXON, C.M., M.W. McCLAIN and K.R. RUSSELL. 1970. Deer food habits and range characteristics in Ohio. Journal of Wildlife Mangement 34(4):870-886.

ONTARIO MINISTRY OF NATURAL RESOURCES. 1976. Management plan for the Rainy River management unit of the Fort Frances administrative district for the period of April 1, 1966 to March 31, 1986. Ontario Ministry of Natural Resources unpublished report, Fort Frances, Ontario. 63 pp.

ONTARIO MINISTRY OF NATURAL RESOURCES. 1980. Background information Fort Frances District land use plan, Northwestern Region. Ontario Ministry of Natural Resources, Fort Frances, Ontario. 119 pp.

ONTARIO MINISTRY OF NATURAL RESOURCES. 1983. Fort Frances district land use guidelines. Ontario Ministry of Natural Resources, Fort Frances, Ontario. 103 pp.

ONTARIO MINISTRY OF NATURAL RESOURCES. 1984b. Standards and guidelines for deer pellet group and winter mortality surveys in Ontario. Ontario Ministry of Natural Resources unpublished report, Toronto, Ontario. 28 pp.

ONTARIO MINISTRY OF NATURAL RESOURCES. 1984a. Standards and guidelines for ranking deer habitat in Ontario. Ontario Ministry of Natural Resources unpublished report, Toronto. 20 pp.

ORMSBY, J.P. and R.S. LUNETTA. 1987. Whitetail deer food availability maps from thematic mapper data. Photogrammetric Engineering and Remote Sensing 53(11): 1585-1589.

OZOGA, J.J. and L.W. GYSEL. 1972. Response of white-tailed deer to winter weather. Journal of Wildlife Management 36:892-896.

OZOGA, J.J., and L.J. VERME. 1970. Winter feeding patterns of penned white-tailed deer. Journal of Wildlife Management 34(2):431-439.

PALA, S. and A. JANO. 1981. Landsat-based forest mapping in Ontario north of latitude 52 degrees north. Pp. 228-232 In Proceedings of the Seventh Canadian Symposium on Remote Sensing, Manitoba Remote Sensing Centre, Winnipeg, Manitoba. 599 pp.

PHILLIPS, T.L. and P.H. SWAIN. 1973. The implementation of the maximum likelihood classification rule assuming a Gaussian density function. Purdue University LARS Information Note 121569. 12 pp.

PLONSKI, W.L. 1974. Normal Yield tables (metric) for major forest species of Ontario. Division of Forests, Ontario Ministry of Natural Resources, Toronto, Ontario. 40 pp.

POTVIN, F. and J. HUOT. 1983. Estimating carrying capacity of a white-tailed deer wintering area in Quebec. Journal of Wildlife Management 47(2):463-475.

POTVIN, F., J. HUOT and F. DUSCHESNEAU. 1981. Deer mortality in the Pohenegamook wintering area, Quebec. Canadian Field-Naturalist 95(1):80-84.

RANSOM, A.B. 1967. Reproductive biology of white-tailed deer in Manitoba. Journal of Wiuldlife Management 31(1):114-123.

RANTA, W.B. and S.E. SHAW. 1982. Whitetailed deer pellet group and habitat inventory study - Wildlife Management Unit 7A and 7B spring/82. Ontario Ministry of Natural Resources Kenora District unpublished report, Kenora, Ontario. 80 pp.

REGELIN, W.L., R.M. BARTMAN, D.W. REICHERT and P.H. NEIL. 1976. The influence of supplemental feed on food habits of tamed deer. United States Department of Agriculture, Forest Service Research Note RM-316. 4 pp.

ROBBINS, C.T. 1973. The biological basis for the determination of carrying capacity. Ph.D. Thesis, Cornell University, Ithaca, New York. 239 pp.

ROBEL, R.J. and P.G. WATT. 1970. Comparison of volumetric and point-analysis procedures to describe deer food habits. Journal of Wildlife Management 34(1):210-213.

RONGSTAD, O.J. and J.R. TESTER. 1969. Movements and habitat use of white-tailed deer in Minnesota. Journal of Wildlife Management 33:366-379.

ROSENFIELD, G.H., K. FITZPATRICK-LINS and H.S. LING. 1982. Sampling for thematic map accuracy testing. Photogrammetric Engineering and Remote Sensing 48(1): 131-137.

ROWE, J.S. 1972. Forest regions of Canada. Canada Department of the Environment, Canadian Forestry Service Publication Number 1300, Ottawa, Ontario. 172 pp.

RUBEC, C.D. and G.M. WICKWARE. 1978. Automated land classification in the boreal zone using Landsat digital data. PP. 127-135 In Proceedings of the Fifth Canadian Symposium on Remote Sensing.

RUTSKE, L.H. 1969. A Minnesota guide to forest game habitat management. Minnesota Department of Conservation Technical Bulletin Number 10. 68 pp.

RYELL, L.A. 1971. Evaluation of pellet group survey for estimated deer populations in Michigan. Michigan State University, East Lansing, Michigan, Ph.D. Thesis. 237 pp.

SAS INSTITUTE INC. 1985a. SAS User's guide: basics, version 5 edition. SAS Institute Inc., Cary North Carolina, 1290 pp.

SAS INSTITUTE INC. 1985b. SAS User's guide: statistics, version 5 edition. SAS Institute Inc., Cary, North Carolina, 956 pp.

SATTERWHITE, M., W. RICE and J. SHIPMAN. 1984. Using landform and vegetative factors to improve the interpretation of Landsat imagery. Photogrammetric Engineering and Remote Sensing 50(1):83-91.

SCHMIDT, J.L. and D.L. GILBERT. 1978. Big game of North America ecology and management. Stackpole Books, Harrisburg, Pennsylvania. 494 pp.

SCHREIER, H. L.C. GOODFELLOW and L.M. LAVKULICH. 1982. The use of digital multi-date Landsat imagery in terrain classification. Photogrammetric Engineering and Remote Sensing 48(1):111-119.

SCOTTER, G.W. 1966. Sieve mesh size as related to volumetric and gravimetric analysis of caribou rumen contents. Canadian Field-Naturalist 80:238-241.

SHANNON, C.E. and W. WEAVER. 1963. The mathematical theory of communication. University of Illinois Press, Urbana, Illinois. 117 pp.

SHAW, S. and T. RIPLEY. 1965. Managing the forest for sustained yield of woody browse for deer. P. 229-233 In Proceedings of the Society of American Foresters, Detroit, Michigan.

SHORT, H.L. 1986. Habitat suitability index models: White-tailed deer in the Gulf of Mexico and South Atlantic coastal plains. United States Fish and Wildlife Service Biological Report 82(10.123). 36 pp.

SHORT, N.M., P.D. LOWMAN, Jr., S.C. FREDEN and W.A. FINCH, Jr. 1976. Mission to earth: Landsat views the earth. NASA SP-360, Washington, D.C. 459 pp.

SILVER, H., N.F. COLOVOS, J.B. HOLTER and H.H. HAYES. 1969. Fasting metabolism of white-tailed deer. Journal of Wildlife Management 33:490-498.

SILVER, H., J.B. HOLTER, N.F. COLOVOS and H.H. HAYES. 1971. Effect of falling temperature on heat production in fasting white-tailed deer. Journal of Wildlife Management 35:37-46.

SKINNER, W.R. and E.S. TELFER. 1974. Spring, summer and fall foods of deer in New Brunswick. Journal of Wildlife Management 38(2):210-214.

SMITH, H.L. and P.L. VERKRUYSSE. 1983. The white-tailed deer in Ontario - its ecology and management. Ontario Ministry of Natural Resources, Wildlife Branch, Toronto, Ontario. 35 pp.

SMITH, P. and E.L. BORCZON. 1977. Managing for deer and timber. Your Forests 10(1). 12 pp.

SMITH, P. and E.L. BORCZON. 1981. Cutting plans for deer and timber in cedar swamps. Ontario Ministry of Natural Resources, Toronto, Ontario. 37 pp.

SNEDECOR, G.W. and W.G. COCHRAN. 1967. Statistical methods, sixth edition. The Iowa State University Press, Ames, Iowa. 593 pp.

SPARKS, D.R. and J.C. MALECHEK. 1968. Estimating percentage dry weight in diets using a microscopic technique. Journal of Range Management 21:264-265.

STEEL, R.G.D. AND J.H. TORRIE. 1960. Principles and procedures of statistics with special reference to the biological sciences. McGraw-Hill Book Company, Inc., Toronto, 481 pp.

STOCKER, M. and F.F. GILBERT. 1977. Vegetation and deer habitat relations in southern Ontario: application of habitat classfication to white-tailed deer. Journal of Applied Ecology. 14:433-444.

STOCKER, M., F.F. GILBERT and D.W. SMITH. 1977. Vegetation and deer habitat relations in southern Ontario: classification of habitat types. Journal of Applied Ecology. 14:419-431.

STORMER, F.A. and W.A. BAUER. 1980. Summer forage use by tame deer in northern Michigan. Journal of Wildlife Management 44:98-106.

STOW, D.A. and J.A. ESTES. 1981. Landsat and digital terrain data for county-level resource management. Photogrammetric Engineering and Remote Sensing 47(2):215-222.

SWEENEY, J.M., M.E. GARNER and R.P. BURJERT. 1984. Analysis of white-tailed deer use of forest clear-cuts. Journal of Wildlife Management 48(2):652-655.

SWICK, R.W. and N.J. BENEVENGA. 1977. Labile protein reserves and protein turnover. Journal of Dairy Science 60:505-515.

TELFER, E.S. 1967. Comparison of moose and deer winter range in Nova Scotia. Journal of Wildlife Management 31(3):418-425.

TELFER, E.S. 1970. Winter habitat selection by moose and white-tailed deer. Journal of Wildlife Management 34(3):553-559.

TELFER, E.S. 1974. Logging as a factor in wildlife ecology in the boreal forest. Forestry Chronicle 50(5):186-190.

TELFER, E.S. 1978. Cervid distribution, browse and snowcover in Alberta. Journal of Wildlife Management 42:352-361.

THOMAS, I.L., L.J. LEWIS and N.P. CHING. 1978. Snow field assessment from Landsat. Photogrammetric Engineering and Remote Sensing 44(4):493-502.

THOMPSON, D.C., G.H. KLASSEN and J. CIHLAR. 1980. Caribou habitat mapping in the southern district of Keewatin, N.W.T.: an application of digital Landsat data. Journal of Applied Ecology 17(1):125-138.

TIERSON, W.C., G.F. MATTFIELD, R.W. SAGE, Jr. and D.F. BEHREND. 1985. Seasonal movements and home ranges of white-tailed deer in the Adirondacks. Journal of Wildlife Management 49(3):766-769.

TODD, W.J., D.G. GEHRING and J.F. HAMAN. 1980. Landsat wildland mapping accuracy. Photogrammetric Engineering and Remote Sensing 46(4):509-520.

TOMM, H.O., J.A. BECK, Jr. and R.J. HUDSON. 1981. Responses of wild ungulates to logging practices in Alberta. Canadian Journal of Forestry Research 11:606-614.

TOWRY, R.K. 1975. Forage production versus forage quality in assessment of winter habitat for deer. Transactions of the Northeast Deer Study Group Meeting 11:133-141.

VANGENDEREN, J.L. and B.F. LOCK. 1977. Testing land-use map accuracy. Photogrammetric Engineering and Remote Sensing 43:1135-1137.

VANGILDER, L.D., O.TORGERSON and W.R. PORATH. 1982. Factors influencing diet selection by white-tailed deer. Journal of Wildlife Management 46(3):711-718.

VAVRA, M. and J.L. HOLECHEK. 1980. Factors influencing microhistological analysis of herbivore diets. Journal of Range Management 33:371-374.

VERME, L.J. 1973. Movements of white-tailed deer in upper Michigan. Journal of Wildlife Management 37(4):545-552.

VERME, L.J. and J.J. OZOGA. 1971. Influence of winter weather on white-tailed deer in upper Michigan. Pp 16-28 In A.O. Haugan (ed.). Proceedings of the Snow and Ice Symposium, Ames, Iowa.

VOLTERRA, V. 1926. Variationa and fluctuations of the number of individuals in animal species living together. Pp. 409-448 In R.N. Chapman (ed.). 1931. Animal Ecology. McGraw-Hill Book Co. Inc., New York, New York. 464 pp.

WALLMO, O.C., L.H. CARPENTER, W.L. REGELIN, R.B. GILL and D.L. BAKER. 1977. Evaluation of deer habitat on a nutritional basis. Journal of Range Management 30(2):122-127.

WALSH, S.J. 1980. Coniferous tree species mapping using Landsat data. Remote Sensing of the Environment 9:11-26.

WARD, A.L. 1970. Stomach content and fecal analysis: methods of forage identification. Pp. 146-158 In Range and Wildlife Habitat Evaluation - A Research Symposium. United States Department of Agriculture, Forest Service Miscellaneous Publication 1147. 220 pp.

WEBER, S.J., W.W. MAUTZ, J.W. LANIER and J.E. WILEY III. 1983. Predictive equations for deer yards in northern New Hampshire. Wildlife Society Bulletin 11(4):331-338.

WETZEL, J.F., J.R. WAMBAUGH and J.M. PEEK. 1975. Appraisal of white-tailed deer winter habitats in northeastern Minnesota. Journal of Wildlife Management 39:59-66.

WHELAN, J.B., A.R. TIPTON, J.F. WILLIAMSON, P.R. JOHANSEN, J.P. McCLURE and N.D. COST. 1979. A comparison of three systems for evaluating forest wildlife habitat. Transactions of the North American Wildlife and Natural Resources Conference 44:392-403.

WHITAKER, G.A., E.R. ROACH and R.H. McCUEN. 1976. Inventorying habitats and rating their value for wildlife species. Proceedings of the Southeastern Association of Fish and Wildlife Agencies 30:590-601.

WILLIAMSON, J.F., J.B. WHELAN and R.A. MEAD. 1978. A computerized wildlife habitat information system. Applications of remote sensing to wildlife management. In Proceedings PECORA IV Symposium, Sioux Falls, South Dakota.

WORK, E.A., Jr. and D.L. REBEL. 1976. Results of the periodic mapping of prairie surface water features using Landsat data: 1972 thru 1974. Environmental Research Institute of Michigan Report Number 116500-1-F, Ann Arbor, Michigan, 219 pp.

WYCKOFF, J. 1980. Evaluating mule deer-winter range relationships through Landsat satellite imagery. Ph.D. Dissertation, University of Utah, Utah, Nevada. 106 pp.

WYCKOFF, J.W. 1981. Evaluating the relationship between mule deer pellet-group data and available winter range, using Landsat imagery. Great Basin Naturalist 41(2):213-220.

8.0 APPENDICES

Appendix 1: Spectral Signature Files for Training Areas used in the Supervised Classification of the Multi-Date Map.

IMAGE PARAMETER FILE = DHXMSA001.MSF;1

WATER

FILE NAME : DHXMSA001 FEATURES : 6 NO. OF SAMPLES : 5112.

FEATURE NO.	NAME	MEAN	NO.	NAME	MEAN
1	BND4	0.2523337173462E+02	2	BND5	0.2242312240601E+02
3	BND6	0.1257120513916E+02	4	BND7	0.1469679236412E+01
5	BSP6	0.1372222232819E+02	6	BSP7	0.7391040802002E+01

COVARIANCE INVE

RSE

ROW	COL	COVARIANCE	INVERSE
1	1	0.1804098963737E+01	0.6139935255051E+00
1	2	0.4981901645660E+00	-0.1566369533539E+00
1	3	0.1071463525295E+00	-0.2312600053847E-01
1	4	-0.5465234443545E-01	0.1308772433549E-01
1	5	-0.3526706993580E+00	0.3486263379455E-01
1	6	-0.3916063308716E+00	0.3621478006244E-01
2	1	0.4981901645660E+00	-0.1566369533539E+00
2	2	0.1775728821754E+01	0.6292222738266E+00
2	3	0.2616904675961E+00	-0.6683782488108E-01
2	4	0.6536453217268E-01	-0.1406144537032E-01
2	5	-0.3058599233627E+00	0.3511620685458E-01
2	6	-0.3280791342258E+00	0.3091456927359E-01
3	1	0.1071463525295E+00	-0.2312600240111E-01
3	2	0.2616904675961E+00	-0.6683782488108E-01
3	3	0.2437891244888E+01	0.4488677978516E+00
3	4	0.5665308237076E+00	-0.9189744293690E-01
3	5	0.4482733309269E+00	-0.3845099359751E-01
3	6	0.2357965707779E+00	-0.2130210585892E-01
4	1	-0.5465234443545E-01	0.1308772433549E-01
4	2	0.6536453217268E-01	-0.1406144630164E-01
4	3	0.5665308237076E+00	-0.9189744293690E-01
4	4	0.2489395380020E+01	0.4303565919399E+00
4	5	0.4525410830975E+00	-0.3138798847795E-01
4	6	0.2357873916626E+00	-0.1453137584031E-01
5	1	-0.3526706993580E+00	0.3486263379455E-01
5	2	-0.3058599233627E+00	0.3511620685458E-01
5	3	0.4482733309269E+00	-0.3845099359751E-01
5	4	0.4525410830975E+00	-0.3138798847795E-01
5	5	0.4816193103790E+01	0.2188841104507E+00
5	6	0.1426885575056E+00	0.2021721331403E-02
6	1	-0.3916063308716E+00	0.3621478378773E-01
6	2	-0.3280791342258E+00	0.3091457113624E-01
6	3	0.2357965707779E+00	-0.2130210585892E-01
6	4	0.2357873916626E+00	-0.1453137677163E-01
6	5	0.1426885575056E+00	0.2021721564233E-02
6	6	0.5148368835449E+01	0.2005460709333E+00

DETERMINANT : 0.3801576843262E+03 PROBABILITY : 0.1000000000000E+01

IMAGE PARAMETER FILE = DHXMSA101.MSF;1

SHALLOW WATER

FILE NAME : DHXMSA101 FEATURES : 6 NO. OF SAMPLES : 546.

FEATURE NO.	NAME	MEAN	NO.	NAME	MEAN
1	BND4	0.3172710609436E+02	2	BND5	0.3140659332275E+02
3	BND6	0.1858058547974E+02	4	BND7	0.3648351669312E+01
5	BSP6	0.2126190567017E+02	6	BSP7	0.9950549125671E+01

COVARIANCE INVE

RSE

ROW	COL	COVARIANCE	INVERSE
1	1	0.8940022468567E+01	0.3461817204952E+00
1	2	0.1089644527435E+02	-0.1936210393906E+00
1	3	0.1053853225708E+02	0.3552357852459E-01
1	4	0.7173587799072E+01	-0.3457922115922E-01
1	5	0.3086295843124E+01	0.1380805857480E-02
1	6	0.2243348598480E+01	-0.5155773460865E-01
2	1	0.1089644527435E+02	-0.1936210393906E+00
2	2	0.2029311943054E+02	0.2220077514648E+00
2	3	0.1893233871460E+01	-0.1247602924705E+00
2	4	0.1151755332947E+02	0.8006568253040E-01
2	5	0.4902465820312E+01	-0.7343658711761E-02
2	6	0.2405475854874E+01	0.3342238813639E-01
3	1	0.1053853225708E+02	0.3552363067865E-01
3	2	0.1893233871460E+02	-0.1247603520751E+00
3	3	0.3737789535522E+02	0.2254530638456E+00
3	4	0.2975316047668E+02	-0.1751610934734E+00
3	5	0.9933916091919E+01	-0.1448611915112E-01
3	6	0.5726017951965E+01	-0.1463889610022E-01
4	1	0.7173587799072E+01	-0.3457925841212E-01
4	2	0.1151755332947E+01	0.8006573468447E-01
4	3	0.2975316047668E+02	-0.1751611381769E+00
4	4	0.3037887001038E+02	0.1886996179819E+00
4	5	0.8796853065491E+01	-0.1820604130626E-01
4	6	0.5274322509766E+01	-0.6604189053178E-02
5	1	0.3086295843124E+01	0.1380805857480E-02
5	2	0.4902465820312E+01	-0.7343652658165E-02
5	3	0.9933916091919E+01	-0.1448612846434E-01
5	4	0.8796853065491E+01	-0.1820603385568E-01
5	5	0.1002115821838E+02	0.1516657024622E+00
5	6	0.3524899721146E+01	-0.5221873894334E-01
6	1	0.2243348598480E+01	-0.5155774205923E-01
6	2	0.2405475854874E+01	0.3342238068581E-01
6	3	0.5726017951965E+01	-0.1463886909187E-01
6	4	0.5274322509766E+01	-0.6604216527194E-02
6	5	0.3524899721146E+01	-0.5221873521805E-01
6	6	0.6531500816345E+01	0.2048512697220E+00

DETERMINANT : 0.2343795156250E+0 PROBABILITY : 0.1000000000000E+01

IMAGE PARAMETER FILE = DHXMSA002.MSF;1

MARSH-RED PIXELS

FILE NAME : DHXMSA002 FEATURES : 6 NO. OF SAMPLES : 1808.

FEATURE NO.	NAME	MEAN	NO.	NAME	MEAN
1	BND4	0.5427655029297E+02	2	BND5	0.7317422485352E+02
3	BND6	0.1271139373779E+03	4	BND7	0.1328290863037E+03
5	BSP6	0.5011117172241E+02	6	BSP7	0.4152655029297E+02

ROW	COL	COVARIANCE	INVERSE
1	1	0.3261621475220E+02	0.2505518496037E+00
1	2	0.6060957336426E+02	-0.1159384399652E+00
1	3	9.6365483989716E+01	-0.1434175297618E+01
1	4	-0.1077089118958E+02	-0.5390478763729E-02
1	5	-0.1697980117798E+02	-0.1296804752201E-02
1	6	-0.1495213031769E+02	0.7504240144044E-02
2	1	0.6060957336426E+02	-0.1159384399652E+00
2	2	0.1295871582031E+02	0.6784062832594E-01
2	3	0.8930824279785E+01	-0.1284028310329E-01
2	4	-0.3094078636169E+02	0.1926213316619E-01
2	5	-0.3923630142212E+02	0.4120724741369E-02
2	6	-0.3348644256592E+02	-0.3226587316021E-02
3	1	0.7875483989716E+01	-0.1434175018221E-01
3	2	0.8930824279785E+01	-0.1284028217196E-01
3	3	0.5713890457153E+02	0.7327438145876E-01
3	4	0.5091532897949E+02	-0.5399243161082E-01
3	5	0.3571997833252E+02	-0.1032120920718E-01
3	6	0.2697952461243E+02	0.5875573959202E-02
4	1	-0.1077089118958E+02	-0.5390478298068E-02
4	2	-0.3094078636169E+02	0.1926213130355E-01
4	3	0.5091532897949E+02	-0.5399243533611E-01
4	4	0.7398450469971E+02	0.6161989271641E-01
4	5	0.5117487716675E+02	-0.1259037759155E-02
4	6	0.4088766098022E+02	-0.5075326655060E-02
5	1	-0.1697980117798E+02	-0.1296804752201E-02
5	2	-0.3923630142212E+02	0.4120719153434E-02
5	3	0.3571997833252E+02	-0.1032118592411E-01
5	4	0.5117487716675E+02	-0.1259065698832E-02
5	5	0.1061696166992E+03	0.7381758093834E+01
5	6	0.8410583496094E+02	-0.7448256015778E-01
6	1	-0.1495213031769E+02	0.7504234556109E-02
6	2	-0.3348644256592E+02	-0.3226578701288E-02
6	3	0.2697952461243E+02	0.5875548347831E-02
6	4	0.4088766098022E+02	-0.5075295921415E-02
6	5	0.8410583496094E+02	-0.7448256015778E-01
6	6	0.7733287048340E+02	0.9462435543537E-01

DETERMINANT : 0.344682560000E+09 PROBABILITY : 0.1000000000000E+01

IMAGE PARAMETER FILE = DHXMSA102.MSF;1

MARSH - BLUE PIXELS

FILE NAME : DHXMSA102 FEATURES : 6 NO. OF SAMPLES : 395.

FEATURE NO.	NAME	MEAN	NO.	NAME	MEAN
1	BND4	0.5690885925293E+02	2	BND5	0.7776202392578E+02
3	BND6	0.1288202514648E+03	4	BND7	0.1323442993164E+03
5	BSP6	0.1194405059814E+03	6	BSP7	0.1003417739868E+03

ROW	COL	COVARIANCE	INVERSE
1	1	0.1688515281677E+02	0.2766492366791E+00
1	2	0.3026268959045E+02	-0.1149725243449E+00
1	3	0.1036167526245E+02	-0.2176846005023E-01
1	4	0.1856598973274E+01	0.9383623488247E-02
1	5	-0.3553299605846E-01	-0.2577865496278E-02
1	6	-0.3710025310516E+01	-0.4355195444077E-02
2	1	0.3026268959045E+02	-0.1149725243449E+00
2	2	0.7031916046143E+02	0.6755808740854E-01
2	3	0.1805393409729E+02	-0.6969879847020E-02
2	4	0.2550761401653E+00	0.4327870439738E-02
2	5	-0.1095812225342E+02	-0.3183734603226E-02
2	6	-0.1721763992310E+02	0.1053620874882E-01
3	1	0.1036167526245E+02	-0.2176846005023E-01
3	2	0.1805393409729E+02	-0.6969879847020E-02
3	3	0.3980329895020E+02	0.6670454889536E-01
3	4	0.2684644699097E+02	-0.4548123478889E-01
3	5	0.3117385864258E+02	-0.8085085079074E-02
3	6	0.2202918815613E+02	0.7689047139138E-02
4	1	0.1856598973274E+01	0.9383622556925E-02
4	2	0.2550761401653E+00	0.4327869508415E-02
4	3	0.2684644699097E+02	-0.4548124223948E-01
4	4	0.3699365615845E+02	0.6925565749407E-01
4	5	0.3974238586426E+02	0.2969463821501E-02
4	6	0.3319670104980E+02	-0.1438545342535E-01
5	1	-0.3553299605846E-01	-0.2577870851383E-02
5	2	-0.1095812225342E+02	-0.3183736000210E-02
5	3	0.3117385864258E+02	-0.8085085079074E-02
5	4	0.3974238586426E+02	0.2969462890178E-02
5	5	0.1595672607422E+03	0.5237016826868E-01
5	6	0.1223895950317E+03	-0.5929844826460E-01
6	1	-0.3710025310516E+01	-0.4355187993497E-02
6	2	-0.1721763992310E+02	0.1053621154279E-01
6	3	0.2202918815613E+02	0.7689048536122E-02
6	4	0.3319670104980E+02	-0.1438545342535E-01
6	5	0.1223895950317E+03	-0.5929844826460E-01
6	6	0.1078343887329E+03	0.8096609264612E-01

DETERMINANT : 0.207940928000E+09 PROBABILITY : 0.1000000000000E+01

IMAGE PARAMETER FILE = DHXMSA003.MSF;1

FEN

FILE NAME : DHXMSA003 FEATURES : 6 NO. OF SAMPLES : 3742.

FEATURE NO.	NAME	MEAN	NO.	NAME	MEAN
1	BND4	0.3923864364624E+02	2	BND5	0.4751175689697E+02
3	BND6	0.7704328918457E+02	4	BND7	0.7808658599854E+02
5	BSP6	0.6894094085693E+02	6	BSP7	0.5916996383667E+02

ROW	COL	COVARIANCE	INVERSE
1	1	0.2169673919678E+02	0.3434428870678E+00
1	2	0.3070008087158E+02	-0.1628331094980E+00
1	3	0.4694145965576E+02	-0.3026108071208E-01
1	4	0.4577359008789E+02	-0.5249793641269E-02
1	5	0.3895215225220E+02	-0.2806647215039E-02
1	6	0.3046244239807E+02	0.1042352244258E-01
2	1	0.3070008087158E+02	-0.1628331243992E+00
2	2	0.5105773925781E+02	0.1473044455051E+00
2	3	0.7190697479248E+02	-0.2345129474998E-01
2	4	0.6994199371338E+02	-0.3861714852974E-02
2	5	0.5899358367920E+02	-0.1831126865000E-02
2	6	0.4594466781616E+02	0.1180531829596E-01
3	1	0.4694145965576E+02	-0.3026105649769E-01
3	2	0.7190697479248E+02	-0.2345127053559E-01
3	3	0.1455514526367E+03	0.1057939976454E+00
3	4	0.1431793670654E+03	-0.7155521959066E-01
3	5	0.1304725952148E+03	-0.9170193225145E-02
3	6	0.1064442672729E+03	0.1409454154782E-02
4	1	0.4577359008789E+02	-0.5249826237559E-02
4	2	0.6994199371338E+02	-0.3861736971885E-02
4	3	0.1431793670654E+03	-0.7155517488718E-01
4	4	0.1539401245117E+03	0.9694273769855E-01
4	5	0.1383656768799E+03	-0.2700783312321E-02
4	6	0.1148863906860E+03	-0.2432014606893E-01
5	1	0.3895215225220E+02	-0.2806607633829E-02
5	2	0.5899358367920E+02	-0.1831155270338E-02
5	3	0.1304725952148E+03	-0.9170161560178E-02
5	4	0.1383656768799E+03	-0.2700833603740E-02
5	5	0.1663480377197E+03	0.6395176053047E-01
5	6	0.1314127197266E+03	-0.5974110215902E-01
6	1	0.3046244239807E+02	0.1042349170893E-01
6	2	0.4594466781616E+02	0.1180535182357E-01
6	3	0.1064442672729E+03	0.1409388729371E-02
6	4	0.1148863906860E+03	-0.2432006783783E-01
6	5	0.1314127197266E+03	-0.5974113568664E-01
6	6	0.1163025894165E+03	0.9144119918346E-01

DETERMINANT : 0.3791175600000E+08 PROBABILITY : 0.1000000000000E+01

IMAGE PARAMETER FILE = DHXMSA004.MSF;1

OPEN BOG

FILE NAME : DHXMSA004 FEATURES : 6 NO. OF SAMPLES : 360.

FEATURE NO.	NAME	MEAN	NO.	NAME	MEAN
1	BND4	0.3600000000000E+02	2	BND5	0.4196389007568E+02
3	BND6	0.9672499847412E+02	4	BND7	0.1057138900757E+03
5	BSP6	0.9094166564941E+02	6	BSP7	0.8499166870117E+02

ROW	COL	COVARIANCE	INVERSE
1	1	0.2004456901550E+02	0.3849793374538E+00
1	2	0.3788300704956E+02	-0.1783619523048E+00
1	3	0.2339554405212E+02	-0.2781014330685E-01
1	4	0.2505849647522E+02	0.3874406218529E-01
1	5	0.2361559867859E+02	-0.3374655265361E-02
1	6	0.1596657371521E+02	-0.1255100127310E-01
2	1	0.3788300704956E+02	-0.1783619672060E+00
2	2	0.8300418090820E+02	0.1208701580763E+00
2	3	0.5183948516846E+02	-0.1048632524908E-01
2	4	0.5864414978027E+02	-0.1759099401534E-01
2	5	0.5169985961914E+02	-0.2695767395198E-01
2	6	0.3468767547607E+02	0.1998065039515E-01
3	1	0.2339554405212E+02	-0.2781015262008E-01
3	2	0.5183948516846E+02	-0.1048632804304E-01
3	3	0.5552019500732E+02	0.1214325651526E+00
3	4	0.6136420440674E+02	-0.6478787213564E-01
3	5	0.4259400939941E+02	-0.1766846515238E-02
3	6	0.3588092041016E+02	-0.1384602300823E-01
4	1	0.2505849647522E+02	0.3874406963587E-01
4	2	0.5864414978027E+02	-0.1759099029005E-01
4	3	0.6136420440674E+02	-0.6478786468506E-01
4	4	0.8388161468506E+02	0.7148101180792E-01
4	5	0.5142897033691E+02	-0.7905705831945E-02
4	6	0.4437326049805E+02	-0.1246162131429E-01
5	1	0.2361559867859E+02	-0.3374645486474E-02
5	2	0.5169985961914E+02	-0.2695767953992E-01
5	3	0.4259400939941E+02	-0.1766845583916E-02
5	4	0.5142897033691E+02	-0.7905703969300E-02
5	5	0.5460097503662E+02	0.8833635598421E-01
5	6	0.3935863494873E+02	-0.4746123775840E-01
6	1	0.1596657371521E+02	-0.1255100686103E-01
6	2	0.3468767547607E+02	0.1998065225780E-01
6	3	0.3588092041016E+02	-0.1384601742029E-01
6	4	0.4437326049805E+02	-0.1246162690222E-01
6	5	0.3935863494873E+02	-0.4746123775840E-01
6	6	0.4369080734253E+02	0.7839393615723E-01

DETERMINANT : 0.1727455000000E+08 PROBABILITY : 0.1000000000000E+01

IMAGE PARAMETER FILE = DHXMSA041.MSF;1

OPEN LOW SHRUB BOG

FILE NAME : DHXMSA041 FEATURES : 6 NO. OF SAMPLES : 133.

FEATURE NO.	NAME	MEAN	NO.	NAME	MEAN
1	BND4	0.3309022521973E+02	2	BND5	0.4321052551270E+02
3	BND6	0.1047443618774E+03	4	BND7	0.1188195495605E+03
5	BSP6	0.9530075073242E+02	6	BSP7	0.9687217712402E+02

ROW	COL	COVARIANCE	INVERSE
1	1	0.2219105005264E+01	0.7252610921860E+00
1	2	0.2359611749649E+01	-0.1249523609877E+00
1	3	0.3303503751755E+01	0.8487257361412E-01
1	4	0.6546638488770E+01	-0.1006767675281E+00
1	5	0.1942471623421E+01	0.2320554107428E-01
1	6	0.2534327745438E+01	0.7516731508076E-02
2	1	0.2359611749649E+01	-0.1249524280429E+00
2	2	0.9955373764038E+02	0.3348990976810E+00
2	3	0.1623626899719E+02	-0.3890342265368E-01
2	4	0.222017097473E+02	-0.5380036681890E-01
2	5	0.1238304901123E+02	-0.2042406797409E-01
2	6	0.1387547302246E+02	0.2940852195024E-02
3	1	0.3303503751755E+01	0.8487258106470E-01
3	2	0.1623626899719E+02	-0.3890335559845E-01
3	3	0.4584280395508E+02	0.1156720295548E+00
3	4	0.5135511398315E+02	-0.6721144169569E-01
3	5	0.2831250000000E+02	0.8039610460401E-02
3	6	0.3396685791016E+02	-0.2141591720283E-01
4	1	0.6546638488770E+01	-0.1006767377257E+00
4	2	0.2222017097473E+02	-0.5380041897297E-01
4	3	0.5135511398315E+02	-0.6721142679453E-01
4	4	0.7448200988770E+02	0.9284055233002E-01
4	5	0.3645643997192E+02	-0.2685083076358E-02
4	6	0.4289299392700E+02	-0.1191016845405E-01
5	1	0.1942471623421E+-1	0.2320555038750E-01
5	2	0.1238304901123E+02	-0.2042401954532E-01
5	3	0.2831250000000E+02	0.8039617910981E-02
5	4	0.3645643997192E+02	-0.2685102634132E-02
5	5	0.4716666793823E+02	0.8292583376169E-01
5	6	0.4141761398315E+02	-0.6840644776821E-01
6	1	0.2534327745438E+01	0.7516725454479E-02
6	2	0.1387547302246E+02	0.2940797712654E-02
6	3	0.3396685791016E+02	-0.2141592279077E-01
6	4	0.4289299392700E+02	-0.1191015355289E-01
6	5	0.4141761398315E+02	-0.6840644776821E-01
6	6	0.4923390197754E+02	0.1017930880189E+00

DETERMINANT : 0.9537446250000E+06 PROBABILITY : 0.1000000000000E+01

IMAGE PARAMETER FILE = DHMSA005.MSF;1

MEDIUM DENSITY TREED BOG

FILE NAME : DHXMSA005 FEATURES : 6 NO. OF SAMPLES : 316.

FEATURE NO.	NAME	MEAN	NO.	NAME	MEAN
1	BND4	0.3134810066223E+02	2	BND5	0.2991455650330E+02
3	BND6	0.7990822601318E+02	4	BND7	0.8267721557617E+02
5	BSP6	0.7734494018555E+02	6	BSP7	0.7087025451660E+02

COVARIANCE INVE

RSE

ROW	COL	COVARIANCE	INVERSE
1	1	0.2843551635742E+01	0.5891277790070E+00
1	2	0.2293353080750E+01	-0.4459388554096E-01
1	3	0.6886111259460E+01	-0.3215688467026E-01
1	4	0.8833333015442E+01	-0.3873641788960E-01
1	5	0.4168452262878E+01	-0.1961118914187E-01
1	6	0.3956547737122E+01	0.1830138638616E-01
2	1	0.2293353080750E+01	-0.4459388926625E-01
2	2	0.6821229934692E+01	0.3453977704048E+00
2	3	0.1270337295532E+02	-0.2532916143537E-01
2	4	0.1645495986938E+02	-0.3924109041691E-01
2	5	0.7813690662384E+01	-0.1791993156075E-01
2	6	0.8319047927856E+01	-0.1758266612887E-01
3	1	0.6886111259460E+01	-0.3215687349439E-01
3	2	0.1270337295532E+02	-0.2532918937504E-01
3	3	0.4530912780762E+02	0.1474474519491E+00
3	4	0.5222420501709E+02	-0.7989377528429E-01
3	5	0.2430793571472E+02	-0.2595669031143E-01
3	6	0.2548333358765E+02	-0.1311331707984E-01
4	1	0.8833333015442E+01	-0.3873641788960E-01
4	2	0.1645495986938E+02	-0.3924107179046E-01
4	3	0.5222420501709E+02	-0.7989377528429E-01
4	4	0.7217460632324E+02	0.1045355275273E+00
4	5	0.3073373031616E+02	-0.1604314893484E-01
4	6	0.3320555496216E+02	-0.2684712968767E-01
5	1	0.4168452262878E+01	-0.1961119286716E-01
5	2	0.7813690662384E+01	-0.1791992783546E-01
5	3	0.2430793571472E+02	-0.2595668099821E-01
5	4	0.3073373031616E+02	-0.1604315638542E-01
5	5	0.2233452415466E+02	0.1225293651223E+00
5	6	0.1654960250854E+02	-0.2361668832600E-01
6	1	0.3956547737122E+01	0.1830138266087E-01
6	2	0.8319047927856E+01	-0.1758266426623E-01
6	3	0.2548333358765E+02	-0.1311333384365E-01
6	4	0.3320555496216E+02	-0.2684711664915E-01
6	5	0.1654960250854E+02	-0.2361668646336E-01
6	6	0.2570039749146E+02	0.1046813502908E+00

DETERMINANT : 0.2262012812500E+06 PROBABILITY : 0.1000000000000E+01

IMAGE PARAMETER FILE = DHXMSA051.MSF;1

HIGH DENSITY TREED BOG

FILE NAME : DHXMSA051 FEATURES : 6 NO. OF SAMPLES : 220.

FEATURE NO.	NAME	MEAN	NO.	NAME	MEAN
1	BND4	0.2797727203369E+02	2	BND5	0.2477727317810E+02
3	BND6	0.6926363372803E+02	4	BND7	0.6998181915283E+02
5	BSP6	0.6764545440674E+02	6	BSP7	0.6058181762695E+02

COVARIANCE INVE

RSE

ROW	COL	COVARIANCE	INVERSE
1	1	0.3401327133179E+01	0.5042752027512E+00
1	2	0.2113655805588E+01	-0.1460385620594E+00
1	3	0.7750428199768E+01	-0.5781856924295E-01
1	4	0.9314640045166E+01	0.4310897551477E-02
1	5	0.3206620931625E+01	-0.1265127095394E-02
1	6	0.2460759162903E+01	0.2231611171737E-02
2	1	0.2113655805588E+01	-0.1460385769606E+00
2	2	0.4183005332947E+01	0.4616646170616E+00
2	3	0.8716466903687E+01	-0.6687909830362E-02
2	4	0.1126983451843E+02	-0.3923758119345E-01
2	5	0.4797374248505E+01	-0.4837403073907E-01
2	6	0.2901826381683E+01	0.3793954849243E-01
3	1	0.7750428199768E+01	-0.5781854689121E-01
3	2	0.8716466903687E+01	-0.6687899120152E-02
3	3	0.5022260284424E+02	0.1578327119350E+00
3	4	0.5906906509399E+02	-0.1071199029684E+00
3	5	0.1758276176453E+02	-0.9945682249963E-03
3	6	0.1612928009033E+02	-0.4674490075558E-02
4	1	0.9314640045166E+01	0.4310886841267E-02
4	2	0.1126983451843E+02	-0.3923758491874E-01
4	3	0.5906906509399E+02	-0.1071199029684E+00
4	4	0.8016381072998E+02	0.1002822369337E+00
4	5	0.2288841247559E+02	0.5296710878611E-03
4	6	0.2122060585022E+02	-0.1515557523817E-01
5	1	0.3206620931625E+01	-0.1265129656531E-02
5	2	0.4797374248505E+01	-0.4837402701378E-01
5	3	0.1758276176453E+02	-0.9945512283593E-03
5	4	0.2288841247559E+02	0.5296617746353E-03
5	5	0.2816609573364E+02	0.7756283134222E-01
5	6	0.1665011405945E+02	-0.5664545670152E-01
6	1	0.2460759162903E+01	0.2231608610600E-02
6	2	0.2901826381683E+01	0.3793954104185E-01
6	3	0.1612928009033E+02	-0.4674502648413E-02
6	4	0.2122060585022E+02	-0.1515556965023E-01
6	5	0.1665011405945E+02	-0.5664544925094E-01
6	6	0.2018065071106E+02	0.1102330461144E+00

DETERMINANT : 0.5129654687500E+06 PROBABILITY : 0.1000000000000E+01

IMAGE PARAMETER FILE = DHXMSA052.MSF;1

LOWLAND CONIFER/CEDAR

FILE NAME : DHXMSA052 FEATURES : 6 NO. OF SAMPLES : 164.

FEATURE NO.	NAME	MEAN	NO.	NAME	MEAN
1	BND4	0.2775000000000E+02	2	BND5	0.2462804794312E+02
3	BND6	0.8435975646973E+02	4	BND7	0.8974390411377E+02
5	BSP6	0.7478048706055E+02	6	BSP7	0.6917682647705E+02

ROW	COL	COVARIANCE	INVERSE
1	1	0.3415644168854E+02	0.3459039926529E+00
1	2	0.1127300620079E+01	-0.8865340054035E-01
1	3	-0.2069018363953E+01	-0.9074498899281E-02
1	4	-0.3610429525375E+01	0.1527467276901E-01
1	5	0.1110429406166E+01	0.3023492172360E-03
1	6	0.1105828166008E+01	-0.4115377739072E-01
2	1	0.1127300620079E+01	-0.8865340799093E-01
2	2	0.3143021583557E+01	0.5114691257477E+00
2	3	-0.4981786727905E+01	-0.1442397106439E-01
2	4	-0.7838190078735E+01	0.5895441770554E-01
2	5	0.1758435606956E+01	-0.5066604167223E-01
2	6	0.9066334366798E+00	-0.3120065853000E-01
3	1	-0.2069018363953E+01	-0.9074489586055E-02
3	2	-0.4981786727905E+01	-0.1442398037761E-01
3	3	0.4748312759399E+02	0.1118634641171E+00
3	4	0.5535659408569E+02	-0.7917772978544E-01
3	5	0.2110045909882E+01	-0.2232458442450E-02
3	6	0.3432898759842E+01	-0.4235418047756E-02
4	1	-0.3610429525375E+01	0.1527466438711E-01
4	2	-0.7838190078735E+01	-0.5895442888141E-01
4	3	0.5535659408569E+02	-0.7917772978544E-01
4	4	0.7978681182861E+02	0.7449272274971E-01
4	5	0.1832822084427E+01	-0.2361938124523E-02
4	6	0.3959739208221E+01	-0.9837743826210E-02
5	1	0.1110429406166E+01	0.3023482859135E-03
5	2	0.1758435606956E+01	-0.5066604167223E-01
5	3	0.2110045909882E+01	-0.2232461702079E-02
5	4	0.1832822084427E+01	-0.2361934166402E-02
5	5	0.1373082828522E+02	0.1109234318137E+00
5	6	0.5861196517944E+01	-0.7255747914314E-01
6	1	0.1105828166008E+01	-0.4115377366543E-01
6	2	0.9066334366798E+00	-0.3120065853000E-01
6	3	0.3432898759842E+01	-0.4235415719450E-02
6	4	0.3959739208221E+01	-0.9837754688856E-02
6	5	0.5861196517944E+01	-0.7255747914314E-01
6	6	0.8097393035889E+01	0.1917363852262E+00

DETERMINANT : 0.3181272812500E+06 PROBABILITY : 0.1000000000000E+01

IMAGE PARAMETER FILE = DHXMSA008.MSF;1

UPLAND CONIFER

FILE NAME : DHXMSA008 FEATURES : 6 NO. OF SAMPLES : 736.

FEATURE NO.	NAME	MEAN	NO.	NAME	MEAN
1	BND4	0.2652173995972E+02	2	BND5	0.2419293403625E+02
3	BND6	0.6854076385498E+02	4	BND7	0.7109646606445E+02
5	BSP6	0.6461548614502E+02	6	BSP7	0.5903125000000E+02

ROW	COL	COVARIANCE	INVERSE
1	1	0.2094727993011E+01	0.5687403678894E+00
1	2	0.8651785850525E+00	-0.1777409315109E+00
1	3	0.6125850081444E+00	-0.4676966462284E-02
1	4	0.4528911709785E+00	-0.1238935976289E-02
1	5	0.9056122303009E+00	-0.2847223170102E-01
1	6	0.5224489569664E+00	-0.1601629890501E-01
2	1	0.8651785850525E+00	-0.1777409315109E+00
2	2	0.2607653141022E+01	0.4615231156349E+00
2	3	0.6020408123732E-01	-0.2821146883070E-01
2	4	-0.8471088409424E+00	0.3210953250527E-01
2	5	0.8035714030266E+00	-0.2009705267847E-01
2	6	0.4035714268684E+00	-0.1156304497272E-01
3	1	0.6125850081444E+00	-0.4676969256252E-02
3	2	0.6020408123732E-01	-0.2821146696806E-01
3	3	0.3026224517822E+02	0.1277264058590E+00
3	4	0.3256938934326E+02	-0.8703722804785E-01
3	5	0.3360544204712E+01	-0.2295527840033E-02
3	6	0.3754421710968E+01	-0.4863821435720E-02
4	1	0.4528911709785E+00	-0.1238934346475E-02
4	2	-0.8471088409424E+00	0.3210952877998E-01
4	3	0.3256938934326E+02	-0.8703722059727E-01
4	4	0.4766292572021E+02	0.8250273019075E-01
4	5	0.4164966106415E+01	-0.3828366985545E-02
4	6	0.4881292343140E+01	-0.1103512290865E-01
5	1	0.9056122303009E+00	-0.2847223170102E-01
5	2	0.8035714030266E+00	-0.2009705081582E-01
5	3	0.3360544204712E+01	-0.2295524347574E-02
5	4	0.4164966106415E+01	-0.3828368848190E-02
5	5	0.1053095245361E+02	0.1154313385487E+00
5	6	0.3216326475143E+01	-0.4663971439004E-01
6	1	0.5224489569664E+00	-0.1601629890501E-01
6	2	0.4035714268684E+00	-0.1156304497272E-01
6	3	0.3754421710968E+01	-0.4863822832704E-02
6	4	0.4881292343140E+01	-0.1103512290865E-01
6	5	0.3216326475143E+01	-0.4663971439004E-01
6	6	0.6881972789764E+01	0.1794789582491E+00

DETERMINANT : 0.9391173437500E+05 PROBABILITY : 0.1000000000000E+01

IMAGE PARAMETER FILE = DHXMSA007.MSF;1

HARDWOOD FOREST

FILE NAME : DHXMSA007 FEATURES : 6 NO. OF SAMPLES: 642.

FEATURE NO.	NAME	MEAN	NO.	NAME	MEAN
1	BND4	0.2646261596680E+02	2	BND5	0.2288784980774E+02
3	BND6	0.1093878479004E+03	4	BND7	0.1265093460083E+03
5	BSP6	0.7257009124756E+02	6	BSP7	0.6580841064453E+02

COVARIANCE INVE

RSE

ROW	COL	COVARIANCE	INVERSE
1	1	0.2820007801056E+01	0.4409585297108E+00
1	2	0.1003607630730E+01	-0.1434857398272E+00
1	3	0.1736154437065E+01	-0.2027115784585E-01
1	4	0.1099453926085E+01	0.4913803655654E-02
1	5	0.2227379083633E+01	-0.1915605366230E-01
1	6	0.1959438323975E+01	-0.1380189694464E-01
2	1	0.1003607630730E+01	-0.1434857547283E+00
2	2	0.2545924425125E+01	0.4928910136223E+00
2	3	0.7909516096115E+00	-0.3731605038047E-01
2	4	-0.5947737693787E+00	0.3877777606249E-01
2	5	0.1925312042236E+01	-0.2801596559584E-01
2	6	0.1551092028618E+01	-0.2798781031743E-02
3	1	0.1736154437065E+01	-0.2027115598321E-01
3	2	0.7909516096115E+00	-0.3731604665518E-01
3	3	0.2973556900024E+02	0.1062113717198E+00
3	4	0.2950702095032E+02	-0.6908105313778E-01
3	5	0.5633385181427E+01	0.7415629457682E-02
3	6	0.6258970260620E+01	-0.1548904553056E-01
4	1	0.1099453926086E+01	0.4913800396025E-02
4	2	-0.5947737693787E+00	0.3877777606249E-01
4	3	0.2950702095032E+02	-0.6908105313778E-01
4	4	0.4475506973267E+02	0.6874751299620E-01
4	5	0.5991419792175E+01	-0.9002081118524E-02
4	6	0.5590483665466E+01	0.5933882668614E-02
5	1	0.2227379083633E+01	-0.1915605552495E-01
5	2	0.1925312042236E+01	-0.2801596745849E-01
5	3	0.5633385181427E+01	0.7415622938424E-02
5	4	0.5991419792175E+01	-0.9002078324556E-02
5	5	0.2177769088745E+02	0.1028203964233E+00
5	6	0.1478042125702E+02	-0.7648112624884E-01
6	1	0.1959438323975E+01	-0.1380189321935E-01
6	2	0.1551092028618E+01	-0.2798777539283E-02
6	3	0.6258970260620E+01	-0.1548904180527E-01
6	4	0.5590483665466E+01	0.5933880805969E-02
6	5	0.1478042125702E+02	-0.7648112624884E-01
6	6	0.1876053047180E+02	0.1186310052872E+00

DETERMINANT : 0.4099858750000E+06 PROBABILITY : 0.1000000000000E+01

IMAGE PARAMETER FILE = DHXMSA009.MSF;1

MIXED FOREST

FILE NAME : DHXMSA009 FEATURES : 6 NO. OF SAMPLES : 477.

FEATURE NO.	NAME	MEAN	NO.	NAME	MEAN
1	BND4	0.2728301811218E+02	2	BND5	0.2420964431763E+02
3	BND6	0.9612158966064E+02	4	BND7	0.1066792449951E+03
5	BSP6	0.7564989471436E+02	6	BSP7	0.6910482025146E+02

ROW	COL	COVARIANCE	INVERSE
1	1	0.4678177356720E+01	0.4442850053310E+00
1	2	0.4835543632507E+01	-0.2246942967176E+00
1	3	-0.5744485378265E+01	0.6283842492849E-02
1	4	-0.8896270751953E+01	-0.4943610168993E-02
1	5	0.3346901237965E+00	-0.7949998602271E-02
1	6	-0.7775735259056E+00	-0.3669654950500E-02
2	1	0.4835543632507E+01	-0.2246942669153E+00
2	2	0.9678637504578E+01	0.2533218562603E+00
2	3	-0.1149002075195E+02	-0.1317533943802E-01
2	4	-0.1819747924805E+02	0.2551184967160E-01
2	5	-0.8823529630899E-01	-0.9853976778686E-02
2	6	-0.2156512498856E+01	0.2471322193742E-01
3	1	-0.5744485378265E+01	0.6283854600042E-02
3	2	-0.1149002075195E+02	-0.1317534130067E-01
3	3	0.7880882263184E+02	0.1012873873115E+00
3	4	0.1016008377075E+03	-0.6998056173325E-01
3	5	0.1345588207245E+01	-0.5148146301508E-02
3	6	0.3216386556625E+01	0.6026493385434E-02
4	1	-0.8896270751953E+01	-0.4943618550897E-02
4	2	-0.1819747924805E+02	0.2551185153425E-01
4	3	0.1016008377075E+03	-0.6998055428267E-01
4	4	0.1500420227051E+03	0.5699765682220E-01
4	5	0.1595588207245E+01	0.3215528791770E-02
4	6	0.5558823585510E+01	-0.4824614152312E-02
5	1	0.3346901237965E+00	-0.7950001396239E-02
5	2	-0.8823529630899E-01	-0.9853973053396E-02
5	3	0.1345588207245E+01	-0.5148147698492E-02
5	4	0.1595588207245E+01	0.3215530421585E-02
5	5	0.1678676414490E+02	0.9782586991787E-01
5	6	0.9711134910583E+01	-0.6575872749090E-01
6	1	-0.7775735259056E+00	-0.3669650759548E-02
6	2	-0.2156512498856E+01	0.2471321821218E-01
6	3	0.3216386556625E+01	0.6026495713741E-02
6	4	0.5558823585510E+01	-0.4824616480619E-02
6	5	0.9711134910583E+01	-0.6575873494148E-01
6	6	0.1488392829895E+02	0.1139798909426E+00

DETERMINANT : 0.3680960500000E+7 PROBABILITY : 0.1000000000000E+01

IMAGE PARAMETER FILE = DHXMSA006.MSF;1

SAND, SOIL & ROCK

FILE NAME : DHXMSA006 FEATURES : 6 NO. OF SAMPLES : 241.

FEATURE NO.	NAME	MEAN	NO.	NAME	MEAN
1	BND4	0.6931120300293E+02	2	BND5	0.8915352630615E+02
3	BND6	0.1126680526733E+03	4	BND7	0.9880082702637E+02
5	BSP6	0.1086680526733E+03	6	BSP7	0.7751452636719E+02

COVARIANCE INVE

RSE

ROW	COL	COVARIANCE	INVERSE
1	1	0.6809650878906E+03	0.1082352548838E+00
1	2	0.9600895996094E+03	-0.7127021998167E-01
1	3	0.7495661621094E+03	-0.8843515068293E-02
1	4	0.5383583374023E+03	0.4378708545119E-02
1	5	0.7703124880791E+00	0.1054766820744E-02
1	6	-0.1043859405518E+03	0.7627444574609E-04
2	1	0.9600895996094E+03	-0.7127021253109E-01
2	2	0.1372822387695E+04	0.6018457561731E-01
2	3	0.1058388549805E+04	-0.2476215735078E-01
2	4	0.7522687377930E+03	0.1731690205634E-01
2	5	0.2763541698456E+01	0.4795434651896E-03
2	6	-0.1469041595459E+03	0.1173768832814E-03
3	1	0.7495661621094E+03	-0.8843517862260E-02
3	2	0.1058388549805E+04	-0.2476215548813E-01
3	3	0.1224780151367E+04	0.7839199155569E-01
3	4	0.1156458374023E+04	-0.5322600156069E-01
3	5	0.7188854217529E+02	-0.5375438369811E-02
3	6	-0.8075416564941E+02	0.2923368941993E-02
4	1	0.5383583374023E+03	0.4378712270409E-02
4	2	0.7522687377930E+03	0.1731690205634E-01
4	3	0.1156458374023E+04	-0.5322601273656E-01
4	4	0.1252802124023E+04	0.3740402683616E-01
4	5	0.8519687652588E+02	0.2891354728490E-02
4	6	-0.4401354217529E+02	-0.1435882877558E-02
5	1	0.7703124880791E+00	0.1054753200151E-02
5	2	0.2763541698456E+01	0.4795521090273E-03
5	3	0.7188854217529E+02	-0.5375435575843E-02
5	4	0.8519687652588E+02	0.2891352167353E-02
5	5	0.3372635498047E+03	0.1319612842053E-01
5	6	0.2693421936035E+03	-0.1229890063405E-01
6	1	-0.1043859405518E+03	0.7629106403328E-04
6	2	-0.1469041595459E+03	0.1173652053694E-03
6	3	-0.8075416564941E+02	0.2923368010670E-02
6	4	-0.4401354217529E+02	-0.1435882062651E-02
6	5	0.2693421936035E+03	-0.1229890063405E-01
6	6	0.2992588500977E+03	0.1507288496941E-01

DETERMINANT : 0.3017691627520E+13 PROBABILITY : 0.1000000000000E+01

IMAGE PARAMETER FILE = DHXMSA010.MSF;1

UNIMPROVED PASTURE

FILE NAME : DHXMSA010 FEATURES : 6 NO. OF SAMPLES : 165.

FEATURE NO.	NAME	MEAN	NO.	NAME	MEAN
1	BND4	0.3970302963257E+02	2	BND5	0.4444242477417E+02
3	BND6	0.1124969711304E+03	4	BND7	0.1204969711304E+03
5	BSP6	0.1078606033325E+03	6	BSP7	0.9161817932129E+02

COVARIANCE INVE

RSE

ROW	COL	COVARIANCE	INVERSE
1	1	0.2129544639587E+02	0.4305948615074E+00
1	2	0.3366272735596E+02	-0.2358689904213E+00
1	3	-0.9123475551605E+00	0.5658708978444E-02
1	4	-0.1274161624908E+02	-0.4581135697663E-02
1	5	0.2726943588257E+02	-0.2313472889364E-01
1	6	0.2191044235229E+02	0.1588037796319E-01
2	1	0.3366272735596E+02	-0.2358689606190E+00
2	2	0.6008955764771E+02	0.1593235284090E+00
2	3	-0.1148247003555E+01	-0.2977070212364E-01
2	4	-0.2239824676514E+02	0.3034266643226E-01
2	5	0.4224504470825E+02	0.1185284927487E-01
2	6	0.3523094558716E+02	-0.1387905981392E-01
3	1	-0.9123475551605E+00	0.5658671259880E-02
3	2	-0.1148247003555E+01	-0.2977067790926E-01
3	3	0.2959298706055E+02	0.1089835092425E+00
3	4	0.2878810882568E+02	-0.7824990898371E-01
3	5	-0.6070884227753E+01	0.2163285622373E-02
3	6	-0.3400914669037E+01	-0.3419955493882E-02
4	1	-0.1274161624908E+02	-0.4581094719470E-02
4	2	-0.2239824676514E+02	0.3034264408052E-01
4	3	0.2878810882568E+02	-0.7824990898371E-01
4	4	0.4782469558716E+02	0.8184879273176E-01
4	5	-0.2342987823486E+02	0.1397236366756E-02
4	6	-0.1778506088257E+02	0.4351019451860E-03
5	1	0.2726943588257E+02	-0.2313470654190E-01
5	2	0.4224504470825E+02	0.1185285206884E-01
5	3	-0.6070884227753E+01	0.2163278870285E-02
5	4	-0.2342987823486E+02	0.1397244865075E-02
5	5	0.1656577758789E+03	0.5120930820704E-01
5	6	0.1247881088257E+03	-0.5855689197779E-01
6	1	0.2191044235229E+02	0.1588035002351E-01
6	2	0.3523094558716E+02	-0.1387906167656E-01
6	3	-0.3400914669037E+01	-0.3419947810471E-02
6	4	-0.1778506088257E+02	0.4350925446488E-03
6	5	0.1247881088257E+03	-0.5855688825250E-01
6	6	0.1070548782349E+03	0.7887858897448E-01

DETERMINANT : 0.8700560000000E+08 PROBABILITY : 0.1000000000000E+01

IMAGE PARAMETER FILE = DHXMSA011.MSF;1

DAL - DK PURPLE

FILE NAME : DHXMSA011 FEATURES : 6 NO. OF SAMPLES : 256.

FEATURE NO.	NAME	MEAN	NO.	NAME	MEAN
1	BND4	0.4278515625000E+02	2	BND5	0.5343750000000E+02
3	BND6	0.9507421875000E+02	4	BND7	0.9633203125000E+02
5	BSP6	0.8067578125000E+02	6	BSP7	0.6613671875000E+02

COVARIANCE INVE

RSE

ROW	COL	COVARIANCE	INVERSE
1	1	0.1314975452423E+02	0.3636085689068E+00
1	2	0.1979240226746E+02	-0.1845160275698E+00
1	3	-0.1074877452850E+02	0.8439754019491E-03
1	4	-0.1972843170166E+02	0.6233090069145E-02
1	5	-0.2720833301544E+01	-0.5957158282399E-04
1	6	-0.2150980472565E+01	-0.1176842022687E-02
2	1	0.1979240226746E+02	-0.1845160275698E+00
2	2	0.3787843322754E+02	0.1267127096653E+00
2	3	-0.1633872604370E+02	-0.1720317266881E-01
2	4	-0.3173039245605E+02	0.1355611346662E-01
2	5	-0.4132352828979E+01	-0.4368854279164E-03
2	6	-0.3240441083908E+01	0.1250514906133E-03
3	1	-0.1074877452850E+02	0.8439849480055E-03
3	2	-0.1633872604370E+02	-0.1720317266881E-01
3	3	0.1014960784912E+03	0.1112605333328E+00
3	4	0.1361950988770E+03	-0.7714930921793E-01
3	5	0.3965147018433E+02	0.3864383324981E-02
3	6	0.3282107925415E+02	-0.6410013884306E-02
4	1	-0.1972843170166E+02	0.6233083084226E-02
4	2	-0.3173039245605E+02	0.1355611346662E-01
4	3	0.1361950988770E+03	-0.7714931666851E-01
4	4	0.2022931365967E+03	0.5996651574969E-01
4	5	0.5633137130737E+02	-0.2842225832865E-02
4	6	0.4575049209595E+02	0.1961925998330E-02
5	1	-0.2720833301544E+01	-0.5957373650745E-04
5	2	-0.4132352828979E+01	-0.4368828958832E-03
5	3	0.3965147018433E+02	0.3864378202707E-02
5	4	0.5633137130737E+02	-0.2842223737389E-02
5	5	0.1730122528076E+03	0.4868885502219E-01
5	6	0.1252877426147E+03	-0.5921455472708E-01
6	1	-0.2150980472565E+01	-0.1176838995889E-02
6	2	-0.3240441083908E+01	0.1250474742847E-03
6	3	0.3282107925415E+02	-0.6410003639758E-02
6	4	0.4575049209595E+02	0.1961921108887E-02
6	5	0.1252877426147E+03	-0.5921455100179E-01
6	6	0.1029892120361E+03	0.8289562910795E-01

DETERMINANT : 0.3123160960000E+09 PROBABILITY : 0.1000000000000E+01

IMAGE PARAMETER FILE = DHXMSA111.MSF;1

DAL - LIME GREEN PIXELS

FILE NAME : DHXMSA111 FEATURES : 6 NO. OF SAMPLES : 44.

FEATURE NO.	NAME	MEAN	NO.	NAME	MEAN
1	BND4	0.4095454406738E+02	2	BND5	0.4988636398315E+02
3	BND6	0.1084318161011E+03	4	BND7	0.1148636398315E+03
5	BSP6	0.1253409118652E+03	6	BSP7	0.1170454559326E+03

COVARIANCE INVE

RSE

ROW	COL	COVARIANCE	INVERSE
1	1	0.3678870010376E+02	0.6869865059853E+00
1	2	0.7690171051025E+02	-0.2765671312809E+00
1	3	0.5927325725555E+01	-0.1126932203770E+00
1	4	-0.1772710800171E+02	0.4462154954672E-01
1	5	0.4013226699829E+02	-0.3246127441525E-01
1	6	0.1479287815094E+02	-0.1643542200327E-01
2	1	0.7690171051025E+02	-0.2765671312809E+00
2	2	0.1721960449219E+03	0.1354177147150E+00
2	3	-0.2601017475128E+01	0.1938982680440E-01
2	4	-0.5613226699829E+02	0.1531014777720E-01
2	5	0.7706250000000E+02	-0.6374197546393E-02
2	6	0.3002834320068E+02	0.1169331837445E-01
3	1	0.5927325725555E+01	-0.1126933470368E+00
3	2	-0.2601017475128E+01	0.1938986405730E-01
3	3	0.6001889419556E+02	0.1314379423857E+00
3	4	0.6715406799316E+02	-0.9286741912365E-01
3	5	0.3152470970154E+02	0.2080290578306E-02
3	6	0.4941860586405E-01	0.9862546809018E-02
4	1	-0.1772710800171E+02	0.4462161287665E-01
4	2	-0.5613226699829E+02	0.1531013008207E-01
4	3	0.6715406799316E+02	-0.9286741167307E-01
4	4	0.1043997116089E+03	0.8891367912292E-01
4	5	0.1739534950256E+02	-0.1973415794933E-01
4	6	-0.7784883499146E+01	0.6737552117556E-02
5	1	0.4013226699829E+02	-0.3246116265655E-01
5	2	0.7706250000000E+02	-0.6374244112521E-02
5	3	0.3152470970154E+02	0.2080259844661E-02
5	4	0.1739534950256E+02	-0.1973414234817E-01
5	5	0.9129941558838E+02	0.4370041564107E-01
5	6	0.3147238349915E+02	-0.2917366288602E-01
6	1	0.1479287815094E+02	-0.1643553562462E-01
6	2	0.3002834320068E+02	0.1169336028397E-01
6	3	0.4941860586405E-01	0.9862570092082E-02
6	4	-0.7784883499146E+01	0.6737536750734E-02
6	5	0.3147238349915E+02	-0.2917365171015E-01
6	6	0.2939244270325E+02	0.6335385888815E-01

DETERMINANT : 0.1094894240000E+09 PROBABILITY : 0.1000000000000E+01

IMAGE PARAMETER FILE = DHXMSA211.MSF;1

DAL - LIME GREEN MOTTLE

FILE NAME : DHXMSA211 FEATURES : 6 NO. OF SAMPLES : 429.

FEATURE NO.	NAME	MEAN	NO.	NAME	MEAN
1	BND4	0.4011888122559E+02	2	BND5	0.4620978927612E+02
3	BND6	0.1067272720337E+03	4	BND7	0.1119510498047E+03
5	BSP6	0.1185944061279E+03	6	BSP7	0.1038251724243E+03

COVARIANCE INVE

RSE

ROW	COL	COVARIANCE	INVERSE
1	1	0.2149751663208E+02	0.3667023181915E+00
1	2	0.3527409362793E+02	-0.1906717717648E+00
1	3	-0.4353096008301E+01	-0.2587098069489E-01
1	4	-0.2031191635132E+02	0.1671681366861E-01
1	5	-0.3986857414246E+01	-0.8302110247314E-02
1	6	-0.4981600284576E+01	-0.7310201879591E-02
2	1	0.3527409362793E+02	-0.1906717568636E+00
2	2	0.6695122528076E+02	0.1220642700791E+00
2	3	-0.1194509315491E+02	-0.8689207024872E-02
2	4	-0.4194742965698E+02	0.9938396513462E-02
2	5	-0.1359462642670E+02	0.2940912265331E-02
2	6	-0.1504030418396E+02	0.6216729991138E-02
3	1	-0.4353096008301E+01	-0.2587097696960E-01
3	2	-0.1194509315491E+02	-0.8689205162227E-02
3	3	0.1047126159668E+03	0.8900726586580E-01
3	4	0.1378750000000E+03	-0.6247585266829E-01
3	5	0.1650584030151E+02	0.3958919551224E-02
3	6	0.1916238403320E+02	0.6218628259376E-03
4	1	-0.2031191635132E+02	0.1671681180596E-01
4	2	-0.4194742965698E+02	0.9938396513462E-02
4	3	0.1378750000000E+03	-0.6247585266829E-01
4	4	0.2131495361328E+03	0.4952995479107E-01
4	5	0.3332593536377E+02	-0.2190560800955E-02
4	6	0.3683995437622E+02	-0.3094106446952E-02
5	1	-0.3986857414246E+01	-0.8302101865411E-02
5	2	-0.1359462642670E+02	0.2940912265331E-02
5	3	0.1650584030151E+02	0.3958919551224E-02
5	4	0.3332593536377E+02	-0.2190560568124E-02
5	5	0.8745210266113E+02	0.5905444175005E-01
5	6	0.7307125854492E+02	-0.5679246038198E-01
6	1	-0.4981600284576E+01	-0.7310210261494E-02
6	2	-0.1504030418396E+02	0.6216729991138E-02
6	3	0.1916238403320E+02	0.6218628259376E-03
6	4	0.3683995437622E+02	-0.3094106446952E-02
6	5	0.7307125854492E+02	-0.5679246410728E-01
6	6	0.7584579467773E+02	0.6999796628952E-01

DETERMINANT : 0.4560237440000E+09 PROBABILITY : 0.1000000000000E+01

IMAGE PARAMETER FILE = DHXMSA311.MSF;1

DAL - BLUE MOTTLE

FILE NAME : DHXMSA311 FEATURES : 6 NO. OF SAMPLES : 428.

FEATURE NO.	NAME	MEAN	NO.	NAME	MEAN
1	BND4	0.3913551330566E+02	2	BND5	0.4314953231812E+02
3	BND6	0.1000864486694E+03	4	BND7	0.1031121520996E+03
5	BSP6	0.1108154220581E+03	6	BSP7	0.9465420532227E+02

COVARIANCE INVE

RSE

ROW	COL	COVARIANCE	INVERSE
1	1	0.1218296241760E+02	0.3866523504257E+00
1	2	0.2018808555603E+02	-0.1873470693827E+00
1	3	-0.1647541046143E+02	-0.9866873733699E-02
1	4	-0.2833138084412E+02	0.1787967165001E-02
1	5	-0.1917622947693E+02	0.1133238896728E-01
1	6	-0.1761563301086E+02	-0.1004874054343E-01
2	1	0.2018808555603E+02	-0.1873470395803E+00
2	2	0.4261460876465E+02	0.1438527852297E+00
2	3	-0.3703395843506E+02	-0.1714960485697E-01
2	4	-0.6200029373169E+02	0.3225355595350E-01
2	5	-0.4044057464600E+02	-0.4490607883781E-02
2	6	-0.3798331451416E+02	0.4345097579062E-02
3	1	-0.1647541046143E+02	-0.9866869077086E-02
3	2	-0.3703395843506E+02	-0.1714960858226E-01
3	3	0.9538173675537E+02	0.8913660794497E-01
3	4	0.1213278656006E+03	-0.6980816274881E-01
3	5	0.7540280914307E+02	-0.5285143386573E-02
3	6	0.6948653411865E+02	0.8181550540030E-02
4	1	-0.2833138084412E+02	0.1787963556126E-02
4	2	-0.6200029373169E+02	0.3225356712937E-01
4	3	0.1213278656006E+03	-0.6980815529823E-01
4	4	0.1779636993408E+03	0.7223554700613E-01
4	5	0.1124016418457E+03	0.9687356650829E-03
4	6	0.1050901641846E+03	-0.1374182663858E-01
5	1	-0.1917622947693E+02	0.1133238710463E-01
5	2	-0.4044057464600E+02	-0.4490594845265E-02
5	3	0.7540280914307E+02	-0.5285184364766E-02
5	4	0.1124016418457E+03	0.9687645360827E-03
5	5	0.1402915649414E+03	0.6357449293137E-01
5	6	0.1202845458984E+03	-0.6313054263592E-01
6	1	-0.1761563301086E+02	-0.1004873216152E-01
6	2	-0.3798331451416E+02	0.4345078952610E-02
6	3	0.6948653411865E+02	0.8181595243514E-02
6	4	0.1050901641846E+03	-0.1374186109751E-01
6	5	0.1202845458984E+03	-0.6313054263592E-01
6	6	0.1164654541016E+03	0.8120242506266E-01

DETERMINANT : 0.9388069600000E+08 PROBABILITY : 0.1000000000000E+01

IMAGE PARAMETER FILE = DHXMSA411.MSF;1

DAL - PINK PIXELS

FILE NAME : DHXMSA441 FEATURES : 6 NO. OF SAMPLES : 24.

FEATURE NO.	NAME	MEAN	NO.	NAME	MEAN
1	BND4	0.3229166793823E+02	2	BND5	0.3191666603088E+02
3	BND6	0.1271666641235E+03	4	BND7	0.1470000000000E+03
5	BSP6	0.1226666641235E+03	6	BSP7	0.1050416641235E+03

COVARIANCE INVE

RSE

ROW	COL	COVARIANCE	INVERSE
1	1	0.2563349246979E+01	0.7608832120895E+00
1	2	0.3112262248993E+01	-0.2196271270514E+00
1	3	-0.7137907505035E+01	-0.5264304950833E-01
1	4	-0.1065251350403E+02	0.6380170583725E-01
1	5	-0.5944293737411E+00	0.2600256353617E-02
1	6	-0.7085598111153E+00	-0.5442120879889E-01
2	1	0.3112262248993E+01	-0.2196271121502E+00
2	2	0.1042756462097E+02	0.2137468308210E+00
2	3	-0.1620278549194E+02	0.7265787571669E-03
2	4	-0.2060869598389E+02	0.6147000938654E-02
2	5	-0.4202785491943E+01	-0.4420313984156E-01
2	6	-0.7257133007050E+01	0.8166360110044E-01
3	1	-0.7137907505035E+01	-0.5264304950833E-01
3	2	-0.1620278549194E+02	0.7265917956829E-03
3	3	0.1440584259033E+03	0.7850050181150E-01
3	4	0.1647826080322E+03	-0.6473612040281E-01
3	5	0.2005842399597E+02	0.3137545660138E-01
3	6	0.2038451004028E+02	-0.3113166615367E-01
4	1	-0.1065251350403E+02	0.6380169838667E-01
4	2	-0.2060869598389E+02	0.6146987900138E-02
4	3	0.1647826080322E+03	-0.6473612040281E-01
4	4	0.2107826080322E+03	0.6049848347902E-01
4	5	0.2834782600403E+02	-0.3274529427290E-01
4	6	0.2330434799194E+02	0.2788950875401E-01
5	1	-0.5944293737411E+00	0.2600248903036E-02
5	2	-0.4202785491943E+01	-0.4420311376452E-01
5	3	0.2005842399597E+02	0.3137545660138E-01
5	4	0.2834782600403E+02	-0.3274529427290E-01
5	5	0.3118885803223E+02	0.1190665587783E+00
5	6	0.2397146797180E+02	-0.1084149181843E+00
6	1	-0.7085598111153E+00	-0.5442120134830E-01
6	2	-0.7257133007050E+01	0.8166357129812E-01
6	3	0.2038451004028E+02	-0.3113166615367E-01
6	4	0.2330434799194E+02	0.2788950875401E-01
6	5	0.2397146797180E+02	-0.1084149181843E+00
6	6	0.2812907600403E+02	0.1470935195684E+00

DETERMINANT : 0.6654708500000E+07 PROBABILITY : 0.1000000000000E+01

IMAGE PARAMETER FILE = DHXMSA511.MSF;1

DAL - MAUVE PIXELS

FILE NAME : DHXMSA511 FEATURES : 6 NO. OF SAMPLES : 202.

FEATURE NO.	NAME	MEAN	NO.	NAME	MEAN
1	BND4	0.4180197906494E+02	2	BND5	0.4834158325195E+02
3	BND6	0.1059851455688E+03	4	BND7	0.1096188125610E+03
5	BSP6	0.9038118743896E+02	6	BSP7	0.7336138916016E+02

COVARIANCE INVE

RSE

ROW	COL	COVARIANCE	INVERSE
1	1	0.3301539230347E+02	0.2575427293777E+00
1	2	0.5661536026001E+02	-0.1106584072113E+00
1	3	0.2435012340546E+02	-0.4383531585336E-01
1	4	-0.2466293525696E+02	0.3993237763643E-01
1	5	0.7906716346741E+01	-0.1967529021204E-01
1	6	0.9726368188858E+00	0.9507990442216E-02
2	1	0.5661536026001E+02	-0.1106584146619E+00
2	2	0.1147434692383E+03	0.6136517599225E-01
2	3	0.6239117145538E+01	0.2284485148266E-02
2	4	-0.3739614486694E+02	-0.5183371715248E-02
2	5	0.3117848157883E+01	0.5746507085860E-02
2	6	-0.5825559616089E+01	0.3940413589589E-03
3	1	0.2435012340546E+01	-0.4383530467749E-01
3	2	0.6239117145538E+01	0.2284477232024E-02
3	3	0.6393532180786E+02	0.7557559013367E-01
3	4	0.7882089233398E+02	-0.4640100896358E-01
3	5	0.2449875640869E+02	-0.9918969590217E-03
3	6	0.2108022308350E+02	-0.2741634612903E-02
4	1	-0.2466293525696E+02	0.3993237018585E-01
4	2	-0.3739614486694E+02	-0.5183365195990E-02
4	3	0.7882089233398E+02	-0.4640100896358E-01
4	4	0.1477500000000E+03	0.3704862296581E-01
4	5	0.2453917884827E+02	0.3896919079125E-03
4	6	0.2645211410522E+02	-0.1327541191131E-02
5	1	0.7906716346741E+01	-0.1967528834939E-01
5	2	0.3117848157883E+01	0.5746507085860E-02
5	3	0.2449875640869E+02	-0.9919018484652E-03
5	4	0.2453917884827E+02	0.3896958660334E-03
5	5	0.1251225128174E+03	0.4931981489062E-01
5	6	0.9092599487305E+02	-0.5519467964768E-01
6	1	0.9726368188858E+00	0.9507986716926E-02
6	2	-0.5825559616089E+01	0.3940413880628E-03
6	3	0.2108022308350E+02	-0.2741627860814E-02
6	4	0.2645211410522E+02	-0.1327546546236E-02
6	5	0.9092599487305E+02	-0.5519467964768E-01
6	6	0.8010261535645E+02	0.7620961219072E-01

DETERMINANT : 0.1405582336000E+10 PROBABILITY : 0.1000000000000E+01

IMAGE PARAMETER FILE = DHXMSA012.MSF;1

EARLY SUCCESSIONAL HARDWOODS & SHRUBS

FILE NAME : DHXMSA012 FEATURES : 6 NO. OF SAMPLES : 88.

FEATURE NO.	NAME	MEAN	NO.	NAME	MEAN
1	BND4	0.3189772796631E+02	2	BND5	0.2960227203369E+02
3	BND6	0.1211022720337E+03	4	BND7	0.1362500000000E+03
5	BSP6	0.8371591186523E+02	6	BSP7	0.7419318389893E+02

COVARIANCE INVE

RSE

ROW	COL	COVARIANCE	INVERSE
1	1	0.7058369159698E+01	0.8359526991844E+00
1	2	0.8958871841431E+01	-0.3974246382713E+00
1	3	0.4067887783051E+01	-0.3870263323188E-01
1	4	-0.3479885101318E+01	0.8336496539414E-02
1	5	0.1562571811676E+02	-0.4133459925652E-01
1	6	0.1242223453522E+02	-0.4086671024561E-01
2	1	0.8958871841431E+01	-0.3974247276783E+00
2	2	0.1426526546478E+02	0.3988895118237E+00
2	3	0.5489583492279E+01	-0.8885921537876E-01
2	4	-0.6025862216949E+01	0.6815888732672E-01
2	5	0.2118462562561E+02	-0.1612320914865E-01
2	6	0.1667546653748E+02	0.6614075507969E-02
3	1	0.4067887783051E+01	-0.3870261460543E-01
3	2	0.5489583492279E+01	-0.8885923027992E-01
3	3	0.3296695327759E+02	0.1848559379578E+00
3	4	0.3452586364746E+02	-0.1265031695366E+00
3	5	0.1500718355179E+01	0.1093909423798E-01
3	6	0.4129310131073E+01	-0.2365638688207E-01
4	1	-0.3479885101318E+01	0.8336482569575E-02
4	2	-0.6025862216949E+01	0.6815890222788E-01
4	3	0.3452586364746E+02	-0.1265031695366E+00
4	4	0.5646551895142E+02	0.1070700734854E+00
4	5	-0.2030747032166E+02	0.1817407086492E-02
4	6	-0.1322126483917E+02	0.1524083688855E-01
5	1	0.1562571811676E+02	-0.4133460670710E-01
5	2	0.2118462562561E+02	-0.1612321101129E-01
5	3	0.1500718355179E+01	0.1093908865005E-01
5	4	-0.2030747032166E+02	0.1817408949137E-02
5	5	0.6301005935669E+02	0.8096202462912E-01
5	6	0.4431968307495E+02	-0.6979933381081E-01
6	1	0.1242223453522E+02	-0.4086665436625E-01
6	2	0.1667546653748E+02	0.6614038720727E-02
6	3	0.4129310131073E+01	-0.2365637384355E-01
6	4	-0.1322126483917E+02	0.1524083036929E-01
6	5	0.4431968307495E+02	-0.6979933381081E-01
6	6	0.4050215530396E+02	0.1182661652565E+00

DETERMINANT : 0.1300330875000E+07 PROBABILITY : 0.1000000000000E+01

Appendix 2: SAS Computer Program used to Predict Habitat Suitability Ranks for the Year-Round Period.

```
//  JOB
//STEP1 EXEC SAS
//INLIB  DD DSN=BDARBY.SASTRY,DISP=(OLD,KEEP),UNIT=DISK,
//               SPACE=(CYL,(4,2),RLSE),VOL=SER=WEEK01
//SYSIN DD *
DATA PREDVARS;
   SET INLIB.PVARS;
ATTRIB NORTH1 LENGTH=$1;
ATTRIB NORTH2 LENGTH=$2;
ATTRIB EAST1 LENGTH=$1;
ATTRIB EAST2 LENGTH=$2;
ATTRIB NORTH10 LENGTH=$1;
ATTRIB EAST10 LENGTH=$3;
ATTRIB B LENGTH=$4;
   NORTH1=SUBSTR(UTM,2,1);
   EAST1=SUBSTR(UTM,1,1);
   NORTH2=SUBSTR(UTM,5,2);
   EAST2=SUBSTR(UTM,3,2);
   NORTH10=SUBSTR(UTM,5,1);
   EAST10=SUBSTR(UTM,1,3);
NORTH=NORTH1 || NORTH2;
EAST=EAST1 || EAST2;
B=EAST10 || NORTH10;
IF B='UE72' OR B='UE71' OR B='UE70' OR B='UE82' THEN OUTPUT;
IF B='UE81' OR B='UE80' OR B='UD89' OR B='UE92' THEN OUTPUT;
IF B='UE91' OR B='UE90' OR B='UD99' OR B='VE02' THEN OUTPUT;
IF B='VE01' OR B='VE00' OR B='VD09' OR B='VD08' THEN OUTPUT;
IF B='VE11' OR B='VE10' OR B='VD19' OR B='VD18' THEN OUTPUT;
IF B='VE21' OR B='VE20' OR B='VD29' OR B='VD28' THEN OUTPUT;
IF B='VE31' OR B='VE30' OR B='VD39' OR B='VD38' THEN OUTPUT;
IF B='VE40' OR B='VD49' OR B='VD48' OR B='VD47' THEN OUTPUT;
IF B='VD59' OR B='VD58' OR B='VD57' OR B='VD68' THEN OUTPUT;
IF B='VD67' THEN OUTPUT;
DROP NORTH1 NORTH2 EAST1 EAST2 NORTH10 EAST10 B;


* ____________________________________________________________
*
* YPRANK: PROGRAM TO GENERATE PREDICTED YEAR-ROUND RANKS FROM WMUSAT
* ____________________________________________________________
*
* READ IN CATPROPS AND EI FOR WMU10:
* ________________________________
*;
DATA YRANK;
   SET PREDVARS;
   CP34  =  (CP3 + CP4);
   CP78  =  (CP7 + CP8);
* ______________________________________________
*
* SET OPTIMAL STANDARDS FOR YEAR-ROUND FOR EACH CATPROP:
* ______________________________________________
*;
OPTLO1  =  0 ;
OPTUP1  =  15;
*;
OPTLO2  =  0 ;
OPTUP2  =  15;
```

```
OPTLO34 =  10 ;
OPTUP34 =  30;
*;
OPTLO5  =  5 ;
OPTUP5  =  15;
*;
OPTLO6  =  10;
OPTUP6  =  30;
*;
OPTLO78 =  3 ;
OPTUP78 =  20;
*;
OPTLO9  =  15;
OPTUP9  =  55;
*;
OPTLO10 =  0 ;
OPTUP10 =  0 ;
* ________________________________________________
*
* CALCULATE PREDICTED RANKS FOR EACH CATPROP:
* ________________________________________________
*;
IF OPTLO1 LE CP1 LE OPTUP1 THEN RANK1 =  1;
IF CP1 LT OPTLO1 THEN RANK1=1+INT(0.99+(OPTLO1-CP1)/(OPTLO1/4));
IF CP1 GT OPTUP1 THEN RANK1=1+INT(0.99+(CP1-OPTUP1)
   /((100-OPTUP1)/4));
IF OPTLO2 LE CP2 LE OPTUP2 THEN RANK2 =  1;
IF CP2 LT OPTLO2 THEN RANK2=1+INT(0.99+(OPTLO2-CP2)/(OPTLO2/4));
IF CP2 GT OPTUP2 THEN
   RANK2=1+INT(0.99+(CP2-OPTUP2)/((100-OPTUP2)/4));
IF OPTLO34 LE CP34 LE OPTUP34 THEN RANK34 = 1;

IF CP34 LT OPTLO34 THEN RANK34=1+INT(0.99+(OPTLO34-CP34)/(OPTLO34/4));
IF CP34 GT OPTUP34 THEN RANK34=1+INT(0.99+(CP34-OPTUP34)/((100-
   OPTUP34)/4));
IF OPTLO5 LE CP5 LE OPTUP5 THEN RANK5 =  1;
IF CP5 LT OPTLO5 THEN RANK5=1+INT(0.99+(OPTLO5-CP5)/(OPTLO5/4));
IF CP5 GT OPTUP5 THEN RANK5=1+INT(0.99+(CP5-OPTUP5)/((100-
   OPTUP5)/4));
IF OPTLO6 LE CP6 LE OPTUP6 THEN RANK6 =  1;
IF CP6 LT OPTLO6 THEN RANK6=1+INT(0.99+(OPTLO6-CP6)/(OPTLO6/4));
IF CP6 GT OPTUP6 THEN RANK6=1+INT(0.99+(CP6-OPTUP6)/((100-
   OPTUP6)/4));
IF OPTLO78 LE CP78 LE OPTUP78 THEN RANK78=1;
IF CP78 LT OPTLO78 THEN RANK78=1+INT(0.99+(OPTLO78-CP78)/
   (OPTLO78/4));
IF CP78 GT OPTUP78 THEN RANK78=1+INT(0.99+(CP78-OPTUP78)/
   ((100-OPTUP78)/4));
IF OPTLO9 LE CP9 LE OPTUP9 THEN RANK9 =  1;
IF CP9 LT OPTLO9 THEN RANK9=1+INT(0.99+(OPTLO9-CP9)/(OPTLO9/4));
IF CP9 GT OPTUP9 THEN RANK9=1+INT(0.99+(CP9-OPTUP9)/((100-OPTUP9)/
   4));
IF OPTLO10 LE CP10 LE OPTUP10 THEN RANK10 =  1;
IF CP10 LT OPTLO10 THEN RANK10=1+INT(0.99+(OPTLO10-CP10)/(OPTLO10/
   4));
IF CP10 GT OPTUP10 THEN RANK10=1+INT(0.99+(CP10-OPTUP10)/((100-
   OPTUP10)/4));
```

```
* ____________________________
*
* CALCULATE RANK FOR EI:
* ____________________________
*;
IF EI LE 12          THEN RANKEI = 1;
IF 12 LT EI LT 21 THEN RANKEI =  0;
IF EI GE 21          THEN RANKEI = -1;
* ______________________________
*
* CALCULATE AVERAGE RANK:
* ______________________________
*;
RANK=INT(0.99+((RANK1+RANK2+RANK34+RANK5+RANK6+RANK78+RANK9
   +RANK10)/8))+RANKEI;
   IF RANK EQ 0 THEN  RANK = 1;
   IF RANK EQ 6 THEN  RANK = 5;
*;
KEEP UTM RANK1 RANK2 RANK34 RANK5 RANK6 RANK78 RANK9 RANK10 RANKEI
   NORTH EAST RANK;
```

Appendix 3: Field Data Form.

MINISTRY OF NATURAL RESOURCES

DEER HABITAT INVENTORY – STAND DESCRIPTION FORM

MANAGEMENT UNIT	DISTRICT	PAGE OF
BASE MAP NUMBER	DATE	RECORDED BY

UTM REF 1 km²	TRN Area	Plot No	BIO CAT	2 – FACTOR PRISM																			10m² Plot											1m² Plot	
				Count By Species												Stand Parameters									0 – 25		26 – 50		51 – 75		76 – 200				
				PW	Pr	Pj	Sb	Sw	Bf	Ce	La	Pb	Po	Bw	OH	WG	Age	Ht	SI	Slp	Asp	CC	H2O	Br Sp.	Br Twigs	UnBr Twigs	Br Twigs	UnBr Twigs	Br Twigs	UnBr Twigs	Br Twigs	UnBr Twigs	Herb	Herb Sp	Cover

* A standard card form, IBM electro 888157, is available for punching statements from this form

Appendix 4: Field Sampling Codes for Use with the Deer Habitat Data Form (Table 9).

UTM REF. Reference number for the 1 sq. km sample site taken from the topographical map sheet (eg. VD2109).

TRN AREA Training Area: 0=No, 1=Yes

PLOT NO. Numbered from 01 to 40 for each sq. km sample site

BIO CAT. Biophysical category:
01=Water
02=Open Wetlands
03=Lowland Conifer
04=Upland Conifer
05=Deciduous Forest
06=Mixed Forest
07=Unimproved Pasture
08=Developed Agricultural Land
09=Shrubs and Early Successional Forest
10=Urban Area

2 Factor Prism Plot

Count By Species: A simple tally of the number of trees included in the 2 factor prism plot.

Stand Parameters:

WG Working group - most common dominant tree species on the 2 fator prism plot. For simplicity, use the same species codes as used for deer browse species given below, plus the following:
38=Black Spruce (*Picea mariana*)
39=Larch (*Larix laricina*)
40=Other Hardwoods
99=Unknown

Age Determined by increment bore from one dominant or co-dominant tree of the working group in the 2 factor prism plot.

Ht Height in meters determined with a clinometer for the same tree for which age was determined.

SI	Site Index - determined from age and height measurements for the dominant and co-dominant tree using the normal yield tables (Plonski, 1974).
Slp	Slope in degrees determined with a clinometer when stand height is measured.
Asp	Aspect: 1=N, 2=NE, 3=E, 4=SE, 5=S, 6=SW, 7=W, 8=NW
CCC	Conifer Crown Closure - ocular estimate over the 2 factor prism plot, expressed as a percentage: 0=0% 2=6-25% 4=51-75% 6=96-100% 1=1-5% 3=26-50% 5=76-95%

10 square meter plot

H20	Surface or permanent water that deer can drink: 0=not present on 1x10 m plot 1=present on 1x10 m plot.
BrSp	Give the codes for browse species listed on the attached sheet that are present on the 1x10 m plot.
Br Twigs	Ocular estimate of the number of browsed twigs of each species in each height category above the ground surface, 0-25 cm, 26-50 cm, 51-75 cm, 76-200 cm: 0=0 2=101-500 4=1001-1500 1=1-100 3=501-1000 5=>1500 Ocular estimates must be verified during a training period in which actual twig counts are made.
Unbr Twigs	Ocular estimate of the number of unbrowsed twigs of each species using the same height categories and codes listed for browsed species. Again, ocular estimates must be verified during a training period in which actual twig counts are made.
% Herb	Ocular estimate of the proportion of the ground surface of the 1x10 m plot obscured by the foliage of herbs: 0=0% 2=6-25% 4=51-75% 6=96-100% 1=1-5% 3=26-50% 5=76-95%

1 square meter plot

Herb Sp	Give the codes for the herb species listed on the attached sheet present on the 1x1 m plot.
% Cover	Ocular estimate of the proportion of the ground surface of the 1x1 m plot obscured by each herb species, using the same codes as listed for % herb on the 1x10 m plot.

Appendix 4 cont'd. ...

DEER BROWSE SPECIES (Wetzel et al., 1975; Mooty, 1976; Garrod, et al., 1981; Ranta and Shaw, 1982).

Code	Scientific Name	Common Name
1.	Abies balsamea	Balsam Fir
2.	Acer rubrum	Red Maple
3.	Acer spicatum	Mountain Maple
4.	Alnus crispa	Mountain Alder
5.	Alnus rugosa	Speckled Alder
6.	Amelanchier spp.	Serviceberries
7.	Betula papyrifera	Paper Birch
8.	Cornus rugosa	Roundleaf Dogwood
9.	Cornus stolonifera	Red-Osier Dogwood
10.	Corylus cornuta	Beaked Hazel
11.	Crateagus spp.	Hawthorn
12.	Diervilla lonicera	Northern Bush Honeysuckle
13.	Epilobium angustifolium	Fireweed
14.	Fraxinus nigra	Black Ash
15.	Ledum groenlandicum	Labrador Tea
16.	Lonicera spp.	Honeysuckles
17.	Picea glauca	White Spruce
18.	Pinus Banksiana	Jack Pine
19.	Pinus resinosa	Red Pine
20.	Pinus strobus	White Pine
21.	Populus balsamifera	Balsam Ploplar
22.	Populus grandidentata	Large-toothed Aspen
23.	Populus tremuloides	Trembling Aspen
24.	Prunus pennsylvanica	Pin Cherry
25.	Prunus virginiana	Choke Cherry
26.	Quercus macrocarpa	Bur Oak
27.	Rhus typhina	Staghorn Sumac
28.	Ribes spp.	Currants
29.	Rubus idaeus	Red Raspberry
30.	Rosa acicularis	Prickly Rose
31.	Salix spp.	Willows
32.	Sorbus americana	Mountain Ash
33.	Thuja occidentalis	White Cedar
34.	Vaccinium angustifolium	Late Sweet Blueberry
35.	Vaccinium myrtilloides	Velvet-leaf Blueberry
36.	Viburnum trilobium	Highbush Cranberry
37.	Viburnum spp.	Viburnums

Appendix 4 cont'd. ...

DEER HERBACEOUS FOODS (Mooty, 1976; Garrod et al., 1981; Ranta and Shaw, 1982).

Code	Scientific Name	Common Name
1.	Anemone canadensis	Wood Anemone
2.	Apocynum androsaemifloium	Spreading Dogbane
3.	Aralia nudicaulis	Wild Sarsaparilla
4.	Asarum canadense	Wild Ginger
5.	Aster macrophyllus	Large-leaf Aster
6.	Aster spp.	Aster
7.	Caltha palustris	Marsh Marigold
8.	Clintonia borealis	Clintonia
9.	Cornus canadensis	Bunchberry
10.	Diervilla lonicera	Northern Bush Honeysuckle
11.	Epilobium angustifolium	Fireweed
12.	Fragaria virginiana	Wild Strawberry
13.	Gaultheria procumbens	Wintergreen
14.	Geranium bicknelli	Bicknell's Cranesbill
15.	Gramineae	Grasses and Sedges
16.	Hieracium spp.	Hawkweed species
17.	Impatiens sp.	Touch-Me-Not
18.	Maianthemum canadense	Lily of the Valley
19.	Menyanthes trifoliata	Buckbean
20.	Oenothera biennis	Common Evening Primrose
21.	Pteridophyta	Bracken Fern
22.	Rudbeckia spp.	Coneflower species
23.	Rumex acetosella	Red Sorrel
24.	Sonchus spp.	Sow-Thistle species
25.	Streptopus americanus	Twist-Stalk
26.	Taraxeum officinale	Common Dandelion
27.	Thalictrum spp.	Meadow Rue
28.	Trifolium spp.	Clover species
29.	Uvalaria spp.	Bellwort species
30.	Vicia americana	Purple Vetch

Appendix 5: SAS Computer Program used to Predict Real Number Habitat Suitability Ranks for the Year-Round Period for Test1.

```
// JOB
//STEP1 EXEC SAS
//INLIB  DD DSN=BDARBY.SASTRY,DISP=(OLD,KEEP),UNIT=DISK,
//             SPACE=(CYL,(4,2),RLSE),VOL=SER=WEEK01
//SYSIN DD *
DATA PREDVARS;
   SET INLIB.PVARS;
ATTRIB NORTH1 LENGTH=$1;
ATTRIB NORTH2 LENGTH=$2;
ATTRIB EAST1 LENGTH=$1;
ATTRIB EAST2 LENGTH=$2;
ATTRIB NORTH10 LENGTH=$1;
ATTRIB EAST10 LENGTH=$3;
ATTRIB B LENGTH=$4;
   NORTH1=SUBSTR(UTM,2,1);
   EAST1=SUBSTR(UTM,1,1);
   NORTH2=SUBSTR(UTM,5,2);
   EAST2=SUBSTR(UTM,3,2);
   NORTH10=SUBSTR(UTM,5,1);
   EAST10=SUBSTR(UTM,1,3);
NORTH=NORTH1 || NORTH2;
EAST=EAST1 || EAST2;
B=EAST10 || NORTH10;
IF B='UE72' OR B='UE71' OR B='UE70' OR B='UE82' THEN OUTPUT;
IF B='UE81' OR B='UE80' OR B='UD89' OR B='UE92' THEN OUTPUT;
IF B='UE91' OR B='UE90' OR B='UD99' OR B='VE02' THEN OUTPUT;
IF B='VE01' OR B='VE00' OR B='VD09' OR B='VD08' THEN OUTPUT;
IF B='VE11' OR B='VE10' OR B='VD19' OR B='VD18' THEN OUTPUT;
IF B='VE21' OR B='VE20' OR B='VD29' OR B='VD28' THEN OUTPUT;
IF B='VE31' OR B='VE30' OR B='VD39' OR B='VD38' THEN OUTPUT;
IF B='VE40' OR B='VD49' OR B='VD48' OR B='VD47' THEN OUTPUT;
IF B='VD59' OR B='VD58' OR B='VD57' OR B='VD68' THEN OUTPUT;
IF B='VD67' THEN OUTPUT;
DROP NORTH1 NORTH2 EAST1 EAST2 NORTH10 EAST10 B;


 * ___________________________________________________________________
 *
 * YPRANK: PROGRAM TO GENERATE PREDICTED YEAR-ROUND RANKS FROM WMUSAT
 * ___________________________________________________________________
 *
 * READ IN CATPROPS AND EI FOR WMU10:
 * ________________________________
 *;
 DATA YRANK;
    SET PREDVARS;
    CP34  =  (CP3 + CP4);
    CP78  =  (CP7 + CP8);
 * ______________________________________________________
 *
 * SET OPTIMAL STANDARDS FOR YEAR-ROUND FOR EACH CATPROP:
 * ______________________________________________________
 *;
 OPTLO1   =   0 ;
 OPTUP1   =   15;
 *;
 OPTLO2   =   0 ;
 OPTUP2   =   15;
```

```
OPTLO34 =  10 ;
OPTUP34 =  30;
*;
OPTLO5  =  5 ;
OPTUP5  =  15;
*;
OPTLO6  =  10;
OPTUP6  =  30;
*;
OPTLO78 =  3 ;
OPTUP78 =  20;
*;
OPTLO9  =  15;
OPTUP9  =  55;
*;
OPTLO10 =  0 ;
OPTUP10 =  0 ;
* ____________________________________________________
*
* CALCULATE PREDICTED RANKS FOR EACH CATPROP:
* ____________________________________________________
*;
IF OPTLO1 LE CP1 LE OPTUP1 THEN RANK1 =  1;
IF CP1 LT OPTLO1 THEN RANK1=1+   (     (OPTLO1-CP1)/(OPTLO1/4));
IF CP1 GT OPTUP1 THEN RANK1=1+   (     (CP1-OPTUP1)
   /((100-OPTUP1)/4));
IF OPTLO2 LE CP2 LE OPTUP2 THEN RANK2 =  1;
IF CP2 LT OPTLO2 THEN RANK2=1+   (     (OPTLO2-CP2)/(OPTLO2/4));
IF CP2 GT OPTUP2 THEN
   RANK2=1+   (     (CP2-OPTUP2)/((100-OPTUP2)/4));
IF OPTLO34 LE CP34 LE OPTUP34 THEN RANK34 = 1;

IF CP34 LT OPTLO34 THEN RANK34=1+   (     (OPTLO34-CP34)/(OPTLO34/4));
IF CP34 GT OPTUP34 THEN RANK34=1+   (     (CP34-OPTUP34)/((100-
   OPTUP34)/4));
IF OPTLO5 LE CP5 LE OPTUP5 THEN RANK5 =  1;
IF CP5 LT OPTLO5 THEN RANK5=1+   (     (OPTLO5-CP5)/(OPTLO5/4));
IF CP5 GT OPTUP5 THEN RANK5=1+   (     (CP5-OPTUP5)/((100-
   OPTUP5)/4));
IF OPTLO6 LE CP6 LE OPTUP6 THEN RANK6 =  1;
IF CP6 LT OPTLO6 THEN RANK6=1 +  (     (OPTLO6-CP6)/(OPTLO6/4));
IF CP6 GT OPTUP6 THEN RANK6=1 +  (     (CP6-OPTUP6)/((100-
   OPTUP6)/4));
IF OPTLO78 LE CP78 LE OPTUP78 THEN RANK78=1;
IF CP78 LT OPTLO78 THEN RANK78=1+   (     (OPTLO78-CP78)/
   (OPTLO78/4));
IF CP78 GT OPTUP78 THEN RANK78=1+   (     (CP78-OPTUP78)/
   ((100-OPTUP78)/4));
IF OPTLO9 LE CP9 LE OPTUP9 THEN RANK9 =  1;
IF CP9 LT OPTLO9 THEN RANK9=1+   (     (OPTLO9-CP9)/(OPTLO9/4));
IF CP9 GT OPTUP9 THEN RANK9=1+   (     (CP9-OPTUP9)/((100-OPTUP9)/
   4));
IF OPTLO10 LE CP10 LE OPTUP10 THEN RANK10 =  1;
IF CP10 LT OPTLO10 THEN RANK10=1+   (     (OPTLO10-CP10)/(OPTLO10/
   4));
IF CP10 GT OPTUP10 THEN RANK10=1+   (     (CP10-OPTUP10)/((100-
   OPTUP10)/4));
```

```
* ______________________________
*
* CALCULATE RANK FOR EI:
* ______________________________
*;
IF EI LE 12         THEN RANKEI =  1;
IF 12 LT EI LT 21   THEN RANKEI =  0;
IF EI GE 21         THEN RANKEI = -1;
* ______________________________
*
* CALCULATE AVERAGE RANK:
* ______________________________
*;
RANK=    (      ((RANK1+RANK2+RANK34+RANK5+RANK6+RANK78+RANK9
   +RANK10)/8))+RANKEI;
   IF RANK EQ 0 THEN   RANK = 1;
   IF RANK EQ 6 THEN   RANK = 5;
*;
KEEP UTM RANK1 RANK2 RANK34 RANK5 RANK6 RANK78 RANK9 RANK10 RANKEI
   NORTH EAST RANK;
```

Appendix 6: SAS Computer Program used to Perform Test1.

```
//  JOB
//STEP1 EXEC SAS
//SYSIN DD *
* ---------------------------------------------------------------------
* T1RANK: PROGRAM TO GENERATE YEAR-ROUND TEST1 RANKS FROM T1DATA
* ---------------------------------------------------------------------
* READ IN T1DATA
* --------------
*;
DATA T1YR;
   ATTRIB UTM LENGTH = $6;
   INPUT UTM PYR CP1 CP2 CP34 CP5 CP6 CP78 CP9 CP10 EI;
* -----------------------------------------------------------------
* SET OPTIMAL STANDARDS FOR YEAR-ROUND FOR EACH CATPROP:
* -----------------------------------------------------------------
*;
OPTLO1   =  0 ;
OPTUP1   =  15;
*;
OPTLO2   =  0 ;
OPTUP2   =  15;
*;
OPTLO34 =  10 ;
OPTUP34 =  30;
*;
OPTLO5   =  5 ;
OPTUP5   =  15;
*;
OPTLO6   =  10;
OPTUP6   =  30;
*;
OPTLO78 =  3 ;
OPTUP78 =  20;
*;
OPTLO9   =  15;
OPTUP9   =  55;
*;
OPTLO10 =  0 ;
OPTUP10 =  0 ;
* ______________________________________________
*
* CALCULATE TEST1 RANKS FOR EACH CATPROP:
* ______________________________________________
*;
IF OPTLO1 LE CP1 LE OPTUP1 THEN RANK1 =  1;
IF CP1 LT OPTLO1 THEN RANK1=1+  (   (OPTLO1-CP1)/(OPTLO1/4));
IF CP1 GT OPTUP1 THEN RANK1=1+  (   (CP1-OPTUP1)
   /((100-OPTUP1)/4));
IF OPTLO2 LE CP2 LE OPTUP2 THEN RANK2 =  1;
IF CP2 LT OPTLO2 THEN RANK2=1+  (   (OPTLO2-CP2)/(OPTLO2/4));
IF CP2 GT OPTUP2 THEN
   RANK2=1+  (   (CP2-OPTUP2)/((100-OPTUP2)/4));
IF OPTLO34 LE CP34 LE OPTUP34 THEN RANK34 = 1;
IF CP34 LT OPTLO34 THEN RANK34=1+  (   (OPTLO34-CP34)/(OPTLO34/4));
IF CP34 GT OPTUP34 THEN RANK34=1+  (   (CP34-OPTUP34)/((100-
```

```
   OPTUP34)/4));
IF OPTLO5 LE CP5 LE OPTUP5 THEN RANK5 =  1;
IF CP5 LT OPTLO5 THEN RANK5=1   (     (OPTLO5-CP5)/(OPTLO5/4));
IF CP5 GT OPTUP5 THEN RANK5=1+   (     (CP5-OPTUP5)/((100-
   OPTUP5)/4));
IF OPTLO6 LE CP6 LE OPTUP6 THEN RANK6 =  1;
IF CP6 LT OPTLO6 THEN RANK6=1+   (     (OPTLO6-CP6)/(OPTLO6/4));
IF CP6 GT OPTUP6 THEN RANK6=1+   (     (CP6-OPTUP6)/((100-
   OPTUP6)/4));
IF OPTLO78 LE CP78 LE OPTUP78 THEN RANK78=1;
IF CP78 LT OPTLO78 THEN RANK78=1+   (     (OPTLO78-CP78)/
   (OPTLO78/4));
IF CP78 GT OPTUP78 THEN RANK78=1+   (     (CP78-OPTUP78)/
   ((100-OPTUP78)/4));
IF OPTLO9 LE CP9 LE OPTUP9 THEN RANK9 =  1;
IF CP9 LT OPTLO9 THEN RANK9=1+   (     (OPTLO9-CP9)/(OPTLO9/4));
IF CP9 GT OPTUP9 THEN RANK9=1+   (     (CP9-OPTUP9)/((100-OPTUP9)/
   4));
IF OPTLO10 LE CP10 LE OPTUP10 THEN RANK10 =  1;
IF CP10 LT OPTLO10 THEN RANK10=1+   (     (OPTLO10-CP10)/(OPTLO10/
   4));
IF CP10 GT OPTUP10 THEN RANK10=1+   (     (CP10-OPTUP10)/((100-
   OPTUP10)/4));
* ______________________________
*
* CALCULATE RANK FOR EI:
* ______________________________
*;
IF EI LE 10       THEN RANKEI = 1;
IF 10 LT EI LT 19 THEN RANKEI =  0;
IF EI GE 19       THEN RANKEI = -1;
* ______________________________
*
* CALCULATE AVERAGE RANK:
* ______________________________
*;
RANK=         ((RANK1+RANK2+RANK34+RANK5+RANK6+RANK78+RANK9
   +RANK10)/8) +RANKEI;
   IF RANK EQ 0 THEN  RANK = 1;
   IF RANK EQ 6 THEN  RANK = 5;
KEEP UTM PYR RANK;
*;
CARDS;
++EMBED T1DATA NOSEQ;
;
```

```
//   JOB
//STEP1 EXEC SAS
//SYSIN DD *
DATA TEST1;
   ATTRIB UTM LENGTH = $6;
   INPUT UTM PYRR RANKR;
   CARDS;
++EMBED T1REALDAT NOSEQ;
PROC CORR COV OUTP=CORROUT;
   VAR PYRR RANKR;
TITLE 'COVARIANCES AND CORRELATIONS PYRR & T1YR (RANKR)';
PROC PRINT DATA=CORROUT;
TITLE2 'OUTPUT DATASET FROM PROC CORR';
```

Appendix 7: SAS Computer Program used to Perform Test2.

```
//BDARBY$  JOB
//STEP1 EXEC SAS
//INLIB DD DSN=BDARBY.TEMP3,DISP=OLD
//SYSIN DD *
DATA ONE;
   ATTRIB UTM LENGTH=$6;
   INPUT UTM PYRR;
   CARDS;
++EMBED YPREALDAT NOSEQ;
DATA TWO;
   INFILE INLIB;
   INPUT UTM$ NPLOT NTHEME NDOMTREE MTBA MCBA MSCBA MSTDAGE
      MSTDHT MFERT MSLOPE MASPECT MCCC MNBSP MBD MNHSP MHD;
   DROP NPLOT;
DATA TEST2;
   MERGE ONE TWO;
   BY UTM;
PROC CANCORR DATA=TEST2 ALL
   VPREFIX=CANVAR VNAME='PREDICTED YR-RD RANKS'
   WPREFIX=CANVAR WNAME='TEST2 SUMMARY VARIABLES';
   VAR PYRR;
   WITH NTHEME NDOMTREE MTBA MCBA MSCBA MSTDAGE MSTDHT
      MFERT MSLOPE MASPECT MCCC MNBSP MBD MNHSP MHD;
   TITLE  'TEST2 RESULTS';
   TITLE2 'CANONICAL CORRELATION OF PREDICTED YEAR-ROUND
      RANKS WITH TEST2 SUMMARY VARIABLES';
```

Appendix 8 : SAS Computer Program used to Perform Test3

```
//   JOB
//STEP1 EXEC SAS
//SYSIN DD *
DATA TEST3;
   ATTRIB UTM LENGTH = $6;
   INPUT UTM PWR  DENS;
   CARDS;
++EMBED T3REALDAT NOSEQ;
PROC CORR COV OUTP=CORROUT;
   VAR PWR  DENS;
TITLE 'COVARIANCES AND CORRELATIONS PWR  &  DENS';
PROC PRINT DATA=CORROUT;
TITLE2 'OUTPUT DATASET FROM PROC CORR';
```

Appendix 9: SAS Printout for Results of the Canonical Correlation between Test 1 Ranks and Test 2 Summary Data.

1 TRIAL OF TEST2 RESULTS 20:44 THURSDAY, NOVEMBER 23, 1989 1
CANONICAL CORRELATION OF TEST1 YEAR-ROUND RANKS WITH TEST2 SUMMARY VARIABLES

SIMPLE UNIVARIATE STATISTICS

66 OBSERVATIONS
1 TEST1 YR-RD RANKS
15 TEST2 SUMMARY VARIABLES

VARIABLE	MEAN	ST DEV
T1YRR	2.3381818	1.095734
NTHEME	16.0606061	6.899005
NDOMTREE	14.8484848	7.417738
MTBA	8.0121652	6.282597
MCBA	2.7077106	3.860013
MSCBA	1.3782768	2.400587
MSTDAGE	18.0132909	12.812045
MSTDHT	7.1409045	4.721823
MFERT	0.6068842	0.372224
MSLOPE	0.1756850	0.520184
MASPECT	0.0464368	0.132810
MCCC	0.4523145	0.613095
MNBSP	2.9612774	1.546930
MBD	750.3636364	1061.478521
MNHSP	3.2447674	1.252288
MHD	28.4449879	19.100468

CORRELATIONS AMONG THE TEST1 YR-RD RANKS

	T1YRR
T1YRR	1.0000

1 TRIAL OF TEST2 RESULTS 20:44 THURSDAY, NOVEMBER 23, 1989 2
CANONICAL CORRELATION OF TEST1 YEAR-ROUND RANKS WITH TEST2 SUMMARY VARIABLES

SIMPLE UNIVARIATE STATISTICS

CORRELATIONS AMONG THE TEST2 SUMMARY VARIABLES

	NTHEME	NDOMTREE	MTBA	MCBA	MSCBA	MSTDAGE	MSTDHT	MFERT
NTHEME	1.0000	0.8062	0.3891	0.1042	0.3385	0.2971	0.4588	0.3636
NDOMTREE	0.8062	1.0000	0.4831	0.2260	0.3170	0.4879	0.5696	0.5300
MTBA	0.3891	0.4831	1.0000	0.5901	0.6072	0.8082	0.8395	0.6465
MCBA	0.1042	0.2260	0.5901	1.0000	0.5710	0.7582	0.3624	0.4003
MSCBA	0.3385	0.3170	0.6072	0.5710	1.0000	0.4977	0.4370	0.1995
MSTDAGE	0.2971	0.4879	0.8082	0.7582	0.4977	1.0000	0.8107	0.8100
MSTDHT	0.4588	0.5696	0.8395	0.3624	0.4370	0.8107	1.0000	0.7419
MFERT	0.3636	0.5300	0.6465	0.4003	0.1995	0.8100	0.7419	1.0000
MSLOPE	0.1556	0.2115	0.1887	0.0906	0.0743	0.2508	0.2066	0.3795
MASPECT	0.1343	0.1027	0.0309	-0.1045	-0.0217	0.0718	0.0937	0.2569
MCCC	0.2063	0.3421	0.5477	0.8388	0.5293	0.7094	0.3976	0.4038
MNBSP	0.4773	0.5790	0.6618	0.1032	0.4040	0.5265	0.8281	0.5466
MBD	0.2753	0.3286	0.4396	-0.0480	0.1293	0.1453	0.3632	0.1501
MNHSP	0.4898	0.4424	0.3624	-0.2044	0.2634	0.1706	0.5083	0.2681
MHD	0.2138	0.0310	-0.2287	-0.3636	-0.1470	-0.2518	-0.1225	-0.0448

	MSLOPE	MASPECT	MCCC	MNBSP	MBD	MNHSP	MHD
NTHEME	0.1556	0.1343	0.2063	0.4773	0.2753	0.4898	0.2138
NDOMTREE	0.2115	0.1027	0.3421	0.5790	0.3286	0.4424	0.0310
MTBA	0.1887	0.0309	0.5477	0.6618	0.4396	0.3624	-0.2287
MCBA	0.0906	-0.1045	0.8388	0.1032	-0.0480	-0.2044	-0.3636
MSCBA	0.0743	-0.0217	0.5293	0.4040	0.1293	0.2634	-0.1470
MSTDAGE	0.2508	0.0718	0.7094	0.5265	0.1453	0.1706	-0.2518
MSTDHT	0.2066	0.0937	0.3976	0.8281	0.3632	0.5083	-0.1225
MFERT	0.3795	0.2569	0.4038	0.5466	0.1501	0.2681	-0.0448
MSLOPE	1.0000	0.6750	0.1780	0.1449	-0.0719	0.1023	0.0666
MASPECT	0.6750	1.0000	-0.0097	0.0961	-0.0427	0.0857	0.2045
MCCC	0.1780	-0.0097	1.0000	0.1239	0.0815	-0.1781	-0.3419
MNBSP	0.1449	0.0961	0.1239	1.0000	0.4937	0.7155	-0.0403
MBD	-0.0719	-0.0427	0.0815	0.4937	1.0000	0.4422	-0.1773
MNHSP	0.1023	0.0857	-0.1781	0.7155	0.4422	1.0000	0.3143
MHD	0.0666	0.2045	-0.3419	-0.0403	-0.1773	0.3143	1.0000

CORRELATIONS BETWEEN THE TEST1 YR-RD RANKS AND THE TEST2 SUMMARY VARIABLES

	NTHEME	NDOMTREE	MTBA	MCBA	MSCBA	MSTDAGE	MSTDHT	MFERT
T1YRR	-0.5274	-0.5111	-0.3097	-0.0363	-0.2371	-0.2025	-0.4099	-0.3051

	MSLOPE	MASPECT	MCCC	MNBSP	MBD	MNHSP	MHD
T1YRR	-0.1161	-0.0456	-0.0821	-0.5966	-0.3130	-0.5431	-0.1056

1 TRIAL OF TEST2 RESULTS 20:44 THURSDAY, NOVEMBER 23, 1989 3

CANONICAL CORRELATION OF TEST1 YEAR-ROUND RANKS WITH TEST2 SUMMARY VARIABLES

CANONICAL CORRELATION ANALYSIS

	CANONICAL CORRELATION	ADJUSTED CANONICAL CORRELATION	APPROX STANDARD ERROR	SQUARED CANONICAL CORRELATION	EIGENVALUE	DIFFERENCE	PROPORTION	CUMULATIVE
					EIGENVALUES OF INV(E)*H = CANRSQ/(1-CANRSQ)			
1	0.735517	0.670907	0.056934	0.540986	1.1786	.	1.0000	1.0000

TESTS OF H0: THE CANONICAL CORRELATION IN THE CURRENT ROW AND ALL THAT FOLLOW ARE ZERO

	LIKELIHOOD RATIO	F	NUM DF	DEN DF	PR > F
1	0.45901419	3.9286	15	50	0.0001

MULTIVARIATE TEST STATISTICS AND EXACT F STATISTICS

S=1 M=6.5 N=24.5

STATISTIC	VALUE	F	NUM DF	DEN DF	PR > F
WILKS' LAMBDA	0.4590142	3.929	15	50	0.0001
PILLAI'S TRACE	0.5409858	3.929	15	50	0.0001
HOTELLING-LAWLEY TRACE	1.178582	3.929	15	50	0.0001
ROY'S GREATEST ROOT	1.178582	3.929	15	50	0.0001

RAW CANONICAL COEFFICIENTS FOR THE TEST1 YR-RD RANKS

	CANVAR1
T1YRR	-.9126300394

1 TRIAL OF TEST2 RESULTS 20:44 THURSDAY, NOVEMBER 23, 1989 4
CANONICAL CORRELATION OF TEST1 YEAR-ROUND RANKS WITH TEST2 SUMMARY VARIABLES

CANONICAL CORRELATION ANALYSIS

RAW CANONICAL COEFFICIENTS FOR THE TEST2 SUMMARY VARIABLES

	CANVAR1
NTHEME	0.039283387
NDOMTREE	0.007041486
MTBA	-0.048423102
MCBA	0.203998140
MSCBA	-0.040948224
MSTDAGE	-0.109753665
MSTDHT	0.047515781
MFERT	1.433992687
MSLOPE	0.159559648
MASPECT	-0.826950262
MCCC	0.378411668
MNBSP	0.530017888
MBD	3.02566E-06
MNHSP	0.248953263
MHD	0.000815749

1 TRIAL OF TEST2 RESULTS 20:44 THURSDAY, NOVEMBER 23, 1989 5
CANONICAL CORRELATION OF TEST1 YEAR-ROUND RANKS WITH TEST2 SUMMARY VARIABLES

CANONICAL CORRELATION ANALYSIS

STANDARDIZED CANONICAL COEFFICIENTS FOR THE TEST1 YR-RD RANKS

	CANVAR1
T1YRR	-1.0000

STANDARDIZED CANONICAL COEFFICIENTS FOR THE TEST2 SUMMARY VARIABLES

	CANVAR1
NTHEME	0.2710
NDOMTREE	0.0522
MTBA	-0.3042
MCBA	0.7874
MSCBA	-0.0983
MSTDAGE	-1.4062
MSTDHT	0.2244
MFERT	0.5338
MSLOPE	0.0830
MASPECT	-0.1098
MCCC	0.2320
MNBSP	0.8199
MBD	0.0032
MNHSP	0.3118
MHD	0.0156

1 TRIAL OF TEST2 RESULTS 20:44 THURSDAY, NOVEMBER 23, 1989 6
CANONICAL CORRELATION OF TEST1 YEAR-ROUND RANKS WITH TEST2 SUMMARY VARIABLES

CORRELATIONS BETWEEN THE TEST1 YR-RD RANKS AND THEIR CANONICAL VARIABLES

	CANVAR1
T1YRR	-1.0000

CORRELATIONS BETWEEN THE TEST2 SUMMARY VARIABLES AND THEIR CANONICAL VARIABLES

	CANVAR1
NTHEME	0.7170
NDOMTREE	0.6949
MTBA	0.4211
MCBA	0.0493
MSCBA	0.3224
MSTDAGE	0.2753
MSTDHT	0.5573
MFERT	0.4147
MSLOPE	0.1578
MASPECT	0.0619
MCCC	0.1117
MNBSP	0.8111
MBD	0.4256
MNHSP	0.7384
MHD	0.1436

CORRELATIONS BETWEEN THE TEST1 YR-RD RANKS AND THE CANONICAL VARIABLES OF THE TEST2 SUMMARY VARIABLES

	CANVAR1
T1YRR	-0.7355

CANONICAL CORRELATION OF TEST1 YEAR-ROUND RANKS WITH TEST2 SUMMARY VARIABLES

CANONICAL STRUCTURE

CORRELATIONS BETWEEN THE TEST2 SUMMARY VARIABLES AND THE CANONICAL VARIABLES OF THE TEST1 YR-RD RANKS

	CANVAR1
NTHEME	0.5274
NDOMTREE	0.5111
MTBA	0.3097
MCBA	0.0363
MSCBA	0.2371
MSTDAGE	0.2025
MSTDHT	0.4099
MFERT	0.3051
MSLOPE	0.1161
MASPECT	0.0456
MCCC	0.0821
MNBSP	0.5966
MBD	0.3130
MNHSP	0.5431
MHD	0.1056

CANONICAL CORRELATION OF TEST1 YEAR-ROUND RANKS WITH TEST2 SUMMARY VARIABLES

CANONICAL REDUNDANCY ANALYSIS

RAW VARIANCE OF THE TEST1 YR-RD RANKS
EXPLAINED BY

THEIR OWN CANONICAL VARIABLES	THE OPPOSITE CANONICAL VARIABLES

MSTDHT	0.1680
MFERT	0.0931
MSLOPE	0.0135
MASPECT	0.0021
MCCC	0.0067
MNBSP	0.3559
MBD	0.0980
MNHSP	0.2950
MHD	0.0112

Appendix 10: SAS Printout for Results of the Canonical Correlation between Predicted Year-Round Ranks and Test 2 Summary Data.

SIMPLE UNIVARIATE STATISTICS

66 OBSERVATIONS
1 PREDICTED YR-RD RANKS
15 TEST2 SUMMARY VARIABLES

VARIABLE	MEAN	ST DEV
PYRR	2.2743939	1.213776
NTHEME	16.0606061	6.899005
NDOMTREE	14.8484848	7.417738
MTBA	8.0121652	6.282597
MCBA	2.7077106	3.860013
MSCBA	1.3782768	2.400587
MSTDAGE	18.0132909	12.812045
MSTDHT	7.1409045	4.721823
MFERT	0.6068842	0.372224
MSLOPE	0.1756850	0.520184
MASPECT	0.0464368	0.132810
MCCC	0.4523145	0.613095
MNBSP	2.9612774	1.546930
MBD	750.3636364	1061.478521
MNHSP	3.2447674	1.252288
MHD	28.4449879	19.100468

CORRELATIONS AMONG THE PREDICTED YR-RD RANKS

	PYRR
PYRR	1.0000

SIMPLE UNIVARIATE STATISTICS

CORRELATIONS AMONG THE TEST2 SUMMARY VARIABLES

	NTHEME	NDOMTREE	MTBA	MCBA	MSCBA	MSTDAGE	MSTDHT	MFERT
NTHEME	1.0000	0.8062	0.3891	0.1042	0.3385	0.2971	0.4588	0.3636
NDOMTREE	0.8062	1.0000	0.4831	0.2260	0.3170	0.4879	0.5696	0.5300
MTBA	0.3891	0.4831	1.0000	0.5901	0.6072	0.8082	0.8395	0.6465
MCBA	0.1042	0.2260	0.5901	1.0000	0.5710	0.7582	0.3624	0.4003
MSCBA	0.3385	0.3170	0.6072	0.5710	1.0000	0.4977	0.4370	0.1995
MSTDAGE	0.2971	0.4879	0.8082	0.7582	0.4977	1.0000	0.8107	0.8100
MSTDHT	0.4588	0.5696	0.8395	0.3624	0.4370	0.8107	1.0000	0.7419
MFERT	0.3636	0.5300	0.6465	0.4003	0.1995	0.8100	0.7419	1.0000
MSLOPE	0.1556	0.2115	0.1887	0.0906	0.0743	0.2508	0.2066	0.3795
MASPECT	0.1343	0.1027	0.0309	-0.1045	-0.0217	0.0718	0.0937	0.2569
MCCC	0.2063	0.3421	0.5477	0.8388	0.5293	0.7094	0.3976	0.4038
MNBSP	0.4773	0.5790	0.6618	0.1032	0.4040	0.5265	0.8281	0.5466
MBD	0.2753	0.3286	0.4396	-0.0480	0.1293	0.1453	0.3632	0.1501
MNHSP	0.4898	0.4424	0.3624	-0.2044	0.2634	0.1706	0.5083	0.2681
MHD	0.2138	0.0310	-0.2287	-0.3636	-0.1470	-0.2518	-0.1225	-0.0448

	MSLOPE	MASPECT	MCCC	MNBSP	MBD	MNHSP	MHD
NTHEME	0.1556	0.1343	0.2063	0.4773	0.2753	0.4898	0.2138
NDOMTREE	0.2115	0.1027	0.3421	0.5790	0.3286	0.4424	0.0310
MTBA	0.1887	0.0309	0.5477	0.6618	0.4396	0.3624	-0.2287
MCBA	0.0906	-0.1045	0.8388	0.1032	-0.0480	-0.2044	-0.3636
MSCBA	0.0743	-0.0217	0.5293	0.4040	0.1293	0.2634	-0.1470
MSTDAGE	0.2508	0.0718	0.7094	0.5265	0.1453	0.1706	-0.2518
MSTDHT	0.2066	0.0937	0.3976	0.8281	0.3632	0.5083	-0.1225
MFERT	0.3795	0.2569	0.4038	0.5466	0.1501	0.2681	-0.0448
MSLOPE	1.0000	0.6750	0.1780	0.1449	-0.0719	0.1023	0.0666
MASPECT	0.6750	1.0000	-0.0097	0.0961	-0.0427	0.0857	0.2045
MCCC	0.1780	-0.0097	1.0000	0.1239	0.0815	-0.1781	-0.3419
MNBSP	0.1449	0.0961	0.1239	1.0000	0.4937	0.7155	-0.0403
MBD	-0.0719	-0.0427	0.0815	0.4937	1.0000	0.4422	-0.1773
MNHSP	0.1023	0.0857	-0.1781	0.7155	0.4422	1.0000	0.3143
MHD	0.0666	0.2045	-0.3419	-0.0403	-0.1773	0.3143	1.0000

CORRELATIONS BETWEEN THE PREDICTED YR-RD RANKS AND THE TEST2 SUMMARY VARIABLES

	NTHEME	NDOMTREE	MTBA	MCBA	MSCBA	MSTDAGE	MSTDHT	MFERT
PYRR	-0.5457	-0.6143	-0.4394	-0.0591	-0.2351	-0.3319	-0.5555	-0.4383

	MSLOPE	MASPECT	MCCC	MNBSP	MBD	MNHSP	MHD
PYRR	-0.2249	-0.2450	-0.1556	-0.6629	-0.3241	-0.5569	-0.1320

1

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CANONICAL CORRELATION OF PREDICTED YEAR-ROUND RANKS WITH TEST2 SUMMARY VARIABLES

CANONICAL CORRELATION ANALYSIS

	CANONICAL CORRELATION	ADJUSTED CANONICAL CORRELATION	APPROX STANDARD ERROR	SQUARED CANONICAL CORRELATION	EIGENVALUE	DIFFERENCE	PROPORTION	CUMULATIVE
					EIGENVALUES OF INV(E)*H = CANRSQ/(1-CANRSQ)			
1	0.784419	0.733927	0.047715	0.615313	1.5995	.	1.0000	1.0000

TESTS OF H0: THE CANONICAL CORRELATION IN THE CURRENT ROW AND ALL THAT FOLLOW ARE ZERO

	LIKELIHOOD RATIO	F	NUM DF	DEN DF	PR > F
1	0.38468677	5.3317	15	50	0.0001

MULTIVARIATE TEST STATISTICS AND EXACT F STATISTICS
S=1 M=6.5 N=24.5

STATISTIC	VALUE	F	NUM DF	DEN DF	PR > F
WILKS' LAMBDA	0.3846868	5.332	15	50	0.0001
PILLAI'S TRACE	0.6153132	5.332	15	50	0.0001
HOTELLING-LAWLEY TRACE	1.599518	5.332	15	50	0.0001
ROY'S GREATEST ROOT	1.599518	5.332	15	50	0.0001

RAW CANONICAL COEFFICIENTS FOR THE PREDICTED YR-RD RANKS

	CANVAR1
PYRR	-.8238750985

CANONICAL CORRELATION ANALYSIS

RAW CANONICAL COEFFICIENTS FOR THE TEST2 SUMMARY VARIABLES

	CANVAR1
NTHEME	-0.009774844
NDOMTREE	0.056895655
MTBA	0.019247177
MCBA	0.112743797
MSCBA	-0.088542698
MSTDAGE	-0.091475067
MSTDHT	0.082292428
MFERT	0.780630076
MSLOPE	-0.173543501
MASPECT	1.925461464
MCCC	0.560479393
MNBSP	0.354572067
MBD	-0.000119313
MNHSP	0.215880332
MHD	0.003960509

CANONICAL CORRELATION ANALYSIS

STANDARDIZED CANONICAL COEFFICIENTS FOR THE PREDICTED YR-RD RANKS

	CANVAR1
PYRR	-1.0000

STANDARDIZED CANONICAL COEFFICIENTS FOR THE TEST2 SUMMARY VARIABLES

	CANVAR1
NTHEME	-0.0674
NDOMTREE	0.4220
MTBA	0.1209
MCBA	0.4352
MSCBA	-0.2126
MSTDAGE	-1.1720
MSTDHT	0.3886
MFERT	0.2906
MSLOPE	-0.0903
MASPECT	0.2557
MCCC	0.3436
MNBSP	0.5485
MBD	-0.1266
MNHSP	0.2703
MHD	0.0756

CANONICAL STRUCTURE

CORRELATIONS BETWEEN THE PREDICTED YR-RD RANKS AND THEIR CANONICAL VARIABLES

	CANVAR1
PYRR	-1.0000

CORRELATIONS BETWEEN THE TEST2 SUMMARY VARIABLES AND THEIR CANONICAL VARIABLES

	CANVAR1
NTHEME	0.6956
NDOMTREE	0.7832
MTBA	0.5601
MCBA	0.0753
MSCBA	0.2997
MSTDAGE	0.4232
MSTDHT	0.7081
MFERT	0.5587
MSLOPE	0.2867
MASPECT	0.3123
MCCC	0.1983
MNBSP	0.8451
MBD	0.4132
MNHSP	0.7100
MHD	0.1683

CORRELATIONS BETWEEN THE PREDICTED YR-RD RANKS AND THE CANONICAL VARIABLES OF THE TEST2 SUMMARY VARIABLES

	CANVAR1
PYRR	-0.7844

CANONICAL CORRELATION OF PREDICTED YEAR-ROUND RANKS WITH TEST2 SUMMARY VARIABLES

CANONICAL STRUCTURE

CORRELATIONS BETWEEN THE TEST2 SUMMARY VARIABLES AND THE CANONICAL VARIABLES OF THE PREDICTED YR-RD RANKS

	CANVAR1
NTHEME	0.5457
NDOMTREE	0.6143
MTBA	0.4394
MCBA	0.0591
MSCBA	0.2351
MSTDAGE	0.3319
MSTDHT	0.5555
MFERT	0.4383
MSLOPE	0.2249
MASPECT	0.2450
MCCC	0.1556
MNBSP	0.6629
MBD	0.3241
MNHSP	0.5569
MHD	0.1320

CANONICAL CORRELATION OF PREDICTED YEAR-ROUND RANKS WITH TEST2 SUMMARY VARIABLES

CANONICAL REDUNDANCY ANALYSIS

RAW VARIANCE OF THE PREDICTED YR-RD RANKS
EXPLAINED BY

THEIR OWN CANONICAL VARIABLES	THE OPPOSITE CANONICAL VARIABLES

	PROPORTION	CUMULATIVE PROPORTION	CANONICAL R-SQUARED	PROPORTION	CUMULATIVE PROPORTION
1	1.0000	1.0000	0.6153	0.6153	0.6153

RAW VARIANCE OF THE TEST2 SUMMARY VARIABLES
EXPLAINED BY

	THEIR OWN CANONICAL VARIABLES			THE OPPOSITE CANONICAL VARIABLES	
	PROPORTION	CUMULATIVE PROPORTION	CANONICAL R-SQUARED	PROPORTION	CUMULATIVE PROPORTION
1	0.1708	0.1708	0.6153	0.1051	0.1051

STANDARDIZED VARIANCE OF THE PREDICTED YR-RD RANKS
EXPLAINED BY

	THEIR OWN CANONICAL VARIABLES			THE OPPOSITE CANONICAL VARIABLES	
	PROPORTION	CUMULATIVE PROPORTION	CANONICAL R-SQUARED	PROPORTION	CUMULATIVE PROPORTION
1	1.0000	1.0000	0.6153	0.6153	0.6153

STANDARDIZED VARIANCE OF THE TEST2 SUMMARY VARIABLES
EXPLAINED BY

	THEIR OWN CANONICAL VARIABLES			THE OPPOSITE CANONICAL VARIABLES	
	PROPORTION	CUMULATIVE PROPORTION	CANONICAL R-SQUARED	PROPORTION	CUMULATIVE PROPORTION
1	0.2757	0.2757	0.6153	0.1696	0.1696

SQUARED MULTIPLE CORRELATIONS BETWEEN THE PREDICTED YR-RD RANKS AND THE FIRST 'M' CANONICAL VARIABLES OF THE TEST2 SUMMARY VARIABLES

M	1
PYRR	0.6153

CANONICAL CORRELATION OF PREDICTED YEAR-ROUND RANKS WITH TEST2 SUMMARY VARIABLES

CANONICAL REDUNDANCY ANALYSIS

SQUARED MULTIPLE CORRELATIONS BETWEEN THE TEST2 SUMMARY VARIABLES AND THE FIRST 'M' CANONICAL VARIABLES OF THE PREDICTED YR-RD RANKS

M	1
NTHEME	0.2978
NDOMTREE	0.3774
MTBA	0.1931
MCBA	0.0035
MSCBA	0.0553
MSTDAGE	0.1102
MSTDHT	0.3085
MFERT	0.1921
MSLOPE	0.0506
MASPECT	0.0600

MSTDAGE	0.1102
MSTDHT	0.3085
MFERT	0.1921
MSLOPE	0.0506
MASPECT	0.0600
MCCC	0.0242
MNBSP	0.4395
MBD	0.1051
MNHSP	0.3102
MHD	0.0174