Mangrove and Mud Flat Mapping, WA.
(from Northern Territory to Shark Bay)

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December 1999

Preamble

This report describes the methods and findings of a mapping project which analysed satellite remotely sensed data to locate and map mangrove and mud occurrences along the Western Australian coastline from the Northern Territory border (Kimberley region) to and including Shark Bay in the south. The report presents the results of the project, which relate ground information and satellite Thematic Mapper (TM) data. Discrimination of mangrove and mud flats areas were the primary objective of the study but the results presented here have wider application in the general area of vegetation mapping and monitoring. The work followed earlier studies of the spectral characteristics for forest cover mapping.

The study has been a collaborative effort between the Department of Conservation and Land Management (CALM), and the Department of Transport (DOT), Western Australia.

Introduction

The location and spatial distribution of mangroves and mud flats are basic data sets, required by both the State and Federal governments. To date only isolated mapping or knowledge of the whereabouts has occurred. The need to precisely locate their distribution, for resource and environmental management purposes, has been identified by government agencies charged with the responsibilities of land and water management.

Satellite remote sensing technologies was seen as the most appropriate means of mapping both mangroves and mud flats. It provides the areal capability plus the spectral sensitivity to accurately discriminate mangrove and mud flats from surrounding vegetation, water variations and soils.

Multispectral remote sensing offers an alternative to that of traditional aerial photography and ground survey methods of mapping.

Ground based methods are not well suited to estimation of the areal extent of mangrove and mudflats along the northern coast, and along with aerial photography are labour intensive, time consuming and expensive.

Satellite data from sensors with fixed, broad spectral bands can provide routine broad-scale synoptic coverage, subject to suitable weather conditions. Satellite remotely sensed data is relatively inexpensive when compared with ground survey or aerial photography. If the multispectral data can reliably identify the mangrove and mud occurrence, then remote sensing offers an attractive complementary approach to mapping vegetation.

Previous research conducted by the department of Conservation and Land Management (CALM) has demonstrated the feasibility of detecting mangrove and mud flats using rectified satellite imagery. Some of these results have been used to map forest occurrences using foliage percentage cover (FPC) estimates, within the Kimberley region of Western Australia (Behn, et al 1999).

The project uses similar techniques to detect mangrove and mud flat locations. The successful application of such a technique provides a method of mapping the locations at a better resolution than is possible with current techniques. This will have a variety of benefits for many agencies interested in coastal zone management and monitoring.

Objective

Use Landsat TM satellite imagery to map the extent/location of coastal mangrove and mud flats along Western Australian coastline from the Northern Territory border (Kimberley) to Exmouth in the Pilbara.

Method

The project method outline is:

- Rectify and co-register the required satellite scenes.;
- Stratify satellite imagery (figure one) into manageable and logical geographical zones;
- Identify and select locations of mangrove and mud flats for training of the image;
- Process the data and prepare maps of mangrove and mud flat areas according to the stratified areas, and
- Field check (ground and possibly by air) a sample of sites in each of the stratified areas.

Satellite Imagery

TM data provide routine broad-scale coverage of an area and should be ideal for mapping and monitoring change. The ground picture element (pixel) size (30m) is practical for broad-area surveys and gives results appropriate for resolution with at least several trees and shrubs per pixel and several pixels per homogeneous area. The ability to monitoring change also becomes possible with the ability to co-register and analyse imagery from various dates.

Thematic Mapper imagery has seven bands - bands one, two and three in the visible parts of the spectrum, band four in the near infrared and bands five and seven in the short-wave infrared portions of the spectrum. Band six is located in the thermal infrared part of the spectrum.

The cloud-free Thematic Mapper images over the coastal regions were geometrically corrected and enhanced using ERMapper image processing software at DOLA's Remote Sensing Services, at the Leeuwin Centre, Perth, WA.

Images were rectified to the WGS84 datum and in Geodetic map projection, using nearest neighbour transformation and then mosaiced together to produce a continuous satellite coverage of the coastline.

The imagery is owned by CALM and by Environment Australia. The dates of the imagery range from 1994 imagery in the Kimberley to 1996 imagery along the Pilbara and Canning coastlines. There were some 30 Landsat scenes or part-there-of, representing 3 gigabyte of date to process.

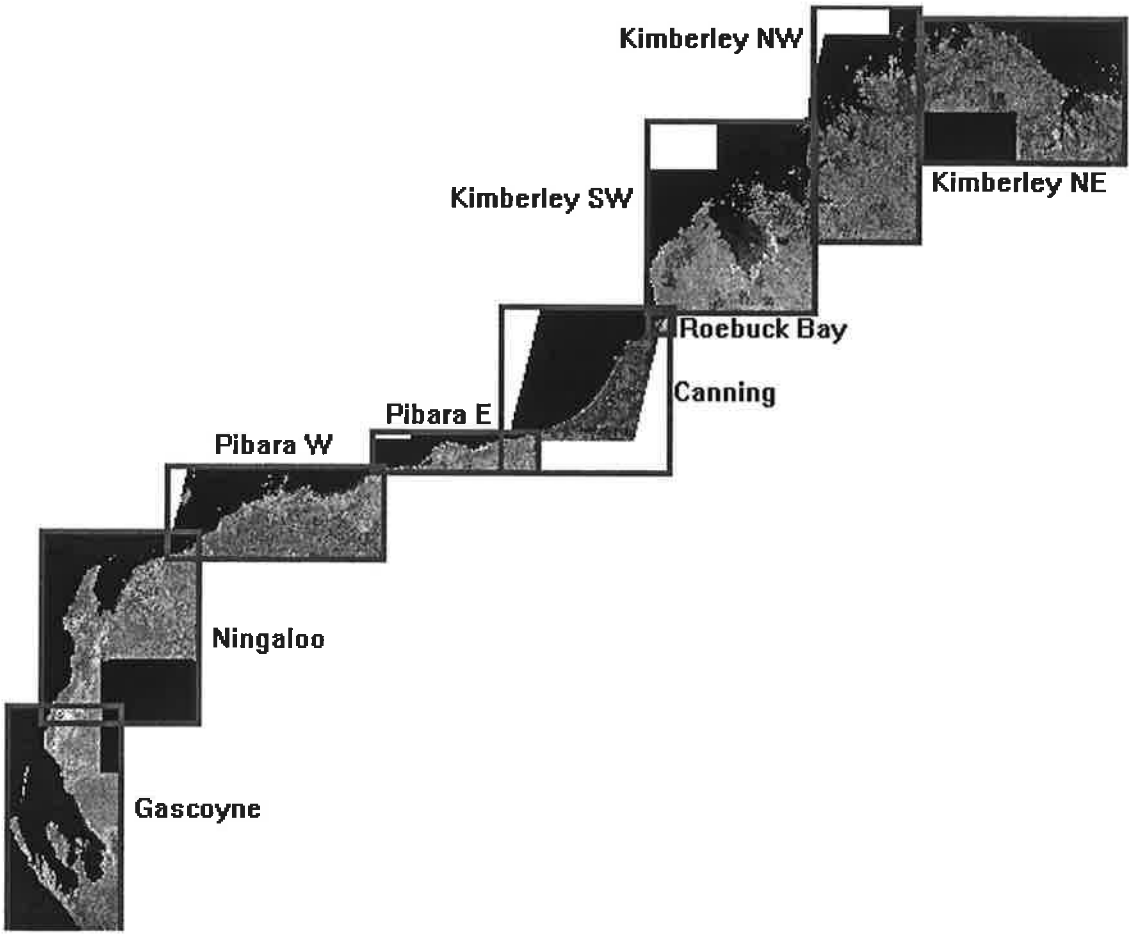

Figure One **Stratify satellite imagery into manageable and logical geographical zones**

Location of Regions

For practicability of processing such large amounts of data, the coast was divided into nine broad areas, as shown in Figure One above. These location and extent of the areas were based on dates of imagery and the complexity of the analysis within differing geographic locations.

Spectral Information

Reflectance spectra of mangrove and mud are the combination of reflectance spectra of trees, understorey, shadow, debris and the soil, to mention a few. Reflectance spectra depend on the proportions of these different elements in a picture element (pixel) which are visible from above.

A canonical variate analysis was used to discriminate between areas of mangrove and mud from other nearby classes of water, vegetation and soils. These areas were then classified into like areas based on their spectral attributes.

The crucial factor in producing spectral maps or enhancements which reliably display areas of mangrove and mud from associated nearby classes is that the spectral separation of the mangrove and mud classes from the other classes is large compared to the variation within classes. If this can be established, then important band combinations that provide the discrimination can be identified and appropriate enhancements produced. A classification mapping approach can also be adopted and pixels can be allocated with confidence to one or other of the classes (or to none).

Canonical variate analysis (CVA) (Anderson, 1958) was used to summarise the class separation between the training site data. Associated routines allow the important discriminating spectral bands to be identified (Campbell 1984: McKay and Campbell, 1982). The CVA analysis summarises the separation between sites in the multivariate (14 bands = 14 dimensions) spectral space. It discovers successive band combinations (vectors) which maximise the site separation. These vectors are referred to as canonical vectors and associated with each is a canonical root - a number that is an index of the separation between sites along that axis. The sum of the canonical roots gives a measure of the overall site separation in all dimensions. The canonical roots form a decreasing sequence. The first CV direction is the single axis that has the greatest separation. Frequently, the site separation in spectral space can be adequately summarised by the first few canonical variates, thus reducing the dimensionality of the data set while maintaining relevant information on site clustering and separation. Band reduction routines are then applied to identify simplified combinations of bands that maintain the separation between groups of sites. The results may be used to identified useful image enhancements, or as input to the classification procedures.

Image Classification

The classification procedures calculate two sets of indices for each pixel - a relative probability of class membership and a typicality for the class. These results are displayed as class maps in different ways to summarise the membership of each class separately, or of several classes together.

Results

Canonical Variate Analysis

The canonical variate plot below (Figure Two) is for the Kimberley NW region. It shows the separation of mangroves and mud from surrounding vegetation, soils and water variations. The analysis (Appendix 1) allows us to classify, with confidence, into the broad-labelled categories shown in Figure Two below.

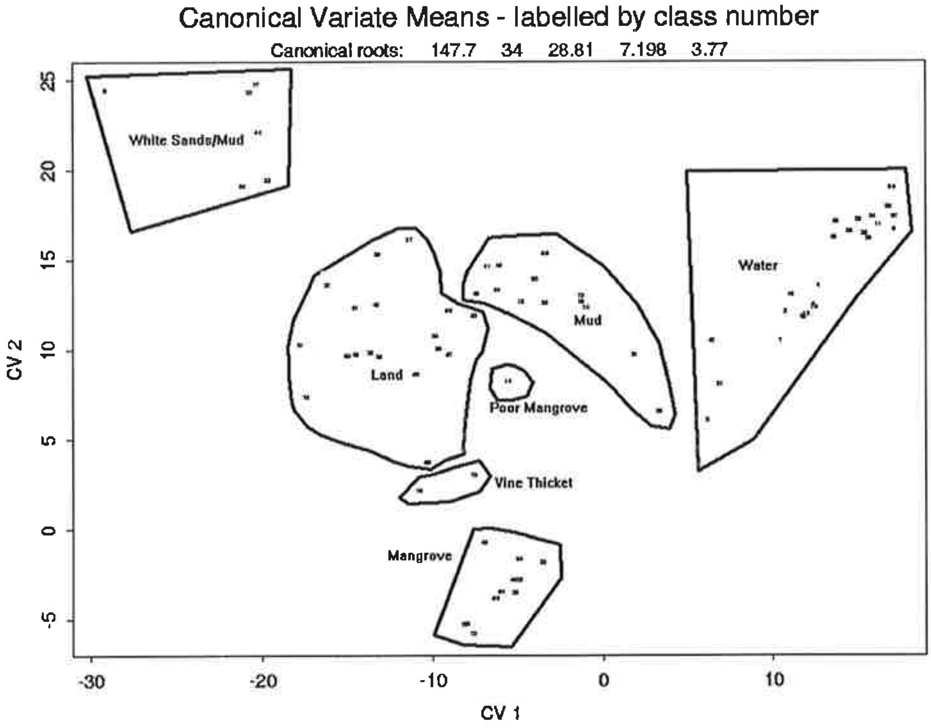

Figure Two Canonical variate (CV) plot of the site data for the Kimberley NE region.

The overall sum of the canonical roots was 221. The first four canonical roots were 148, 34, 29 and 7, which explained 98% of the site separations (Appendix 1).

Figure Two shows the ordination of the site canonical variate means for the first two canonical vectors. A separation of two units along any vector on Figure Two indicates that sufficient spectral differences exist to enable good discrimination between sites. The mangrove and mud sites plot in distinctly different regions of the graph, thereby suggesting their significant difference in spectral characteristics and their spectral separability.

It is notable in Figure Two that the mangrove and mud sites are generally well separated. However, there is also considerable variation within these super-classes, indicating spectral separation in the type of vegetation and ground information of exposed soil, moisture.

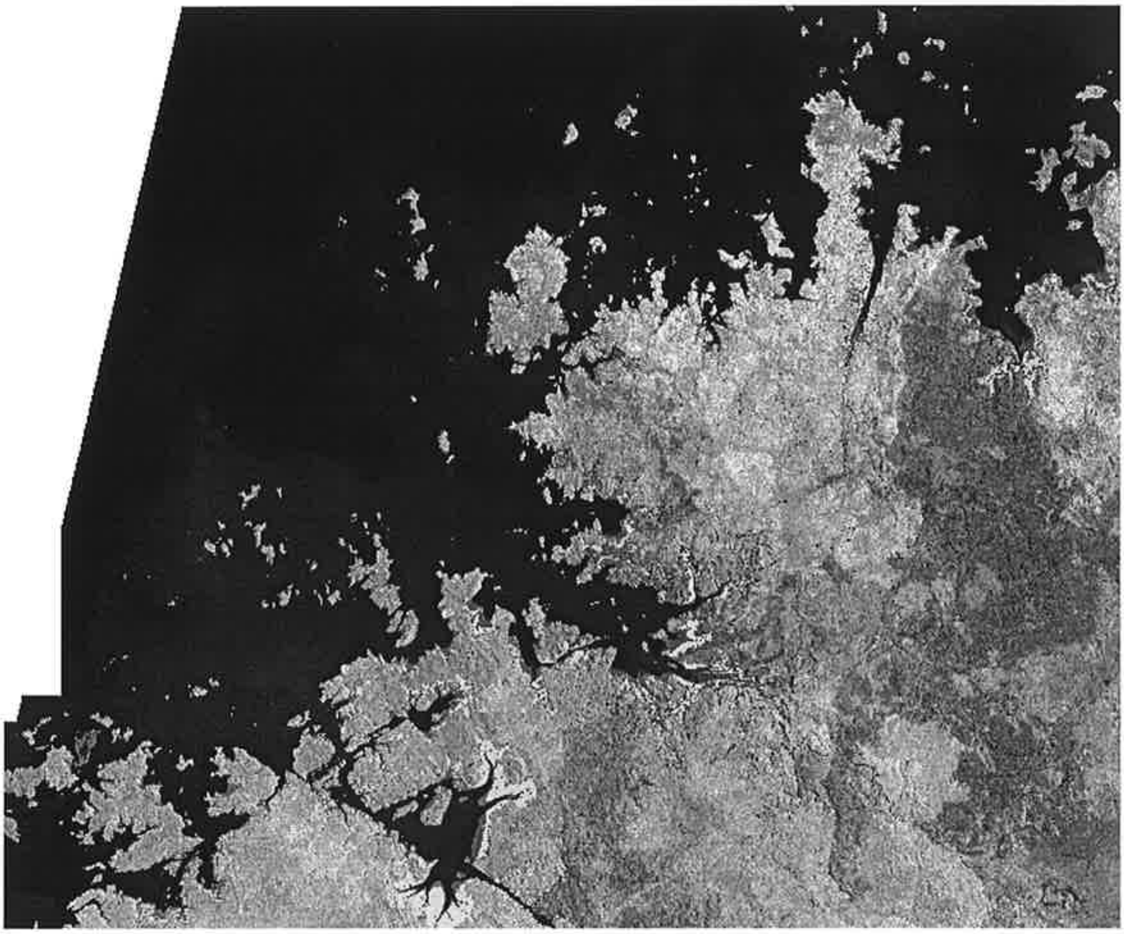

Figure Three Satellite enhanced image of Kimberley NW region showing "super-class' areas of mangrove (yellow) and areas of (mud) grey.

The sites were to be grouped into clusters or 'super-classes'. The mangrove and mud represented sites being super-classes 1, 2

Conclusions

The results of this project indicate that multi-spectral Thematic Mapper data can provide discrimination of occurrences of mangrove and mud flat and the areal extent over large tracts of Western Australian coast.

A classifier, derived from the analysis, has proved to be a useful mapping method on the areal extent from which it was derived.

The assessment of the accuracy of the allocation maps is limited by the amount of accurate ground information available. Validation of spectral allocation against accurate ground information must be made before the proportion of correctly labelled pixels for each class and errors of omission and commission can be calculated. Detailed ground information was not available for the project area. From limited field inspection, in both cases, the general distribution of mangrove and mud flat as depicted on the classified image is consistent with the known information previously obtained by mangrove and mud flat interpretation mapping by CALM officers.

A combination of fieldwork and image mapping is likely to provide the most efficient information. The statistical analysis confirms that discrimination of mangrove and mud flat, within the heath vegetation of the south coast, is possible using multi-spectral, multi-temporal TM satellite data acquired at the appropriate time. The results provide for the use of such data for more widespread mapping of dieback occurrences. For the purpose of dieback detection, a method that is accurate on a broadscale as the results in this study would be valuable. However, this study does not yet provide a general data treatment that can be routinely applied in all locations. Further refinement and verification of spectral combinations will be required to determine which treatments will work across the variations in natural vegetation/forest environments where dieback occurs. The accuracy and reliability of the remote sensing methods is likely to be improved if ancillary data, for example, historical aerial photography, soil properties, topography, is included into the analysis. The analysis of spectral and other information using Geographical Information Systems (GIS) technology should be investigated.

In summary, the mangrove and mud project using multi-spectral TM data has shown the usefulness of spectral information for accurately discriminating mangrove and mud occurrences over large areas of varying coastal terrain of Western Australia. These results provide a basis for the adoption of a technique to locate and map mangrove and mud occurrences within other locations of concern. It also provides the basis for a broad-scale mapping monitoring project for mangrove communities

Acknowledgments

The authors are grateful to Environment Australia for supplying large areas of satellite data used in the project. Appreciation is also expressed to the Department of Land Administration (DOLA) WA, Department of Conservation and Land Management (CALM) WA and the Department of Transport (DOT) WA for their support with the project.

References

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Appendix 1

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RBSTCV - Canonical Variate Analysis Output


Image file: kimb_nw
Channels:    1   2   3   4   5

Area file: kimb_nw.are
Area Description: Regions extracted from ERMapper header file


   1:  Class    1: Number of pixels = 4704   "deep water 22"
   2:  Class    2: Number of pixels =  828   "deep water 19"
   3:  Class    3: Number of pixels =  432   "deep water 15"
   4:  Class    4: Number of pixels = 2652   "deep water 14"
   5:  Class    5: Number of pixels = 1482   "deep water12"
   6:  Class    6: Number of pixels = 2132   "deep water11"
   7:  Class    7: Number of pixels = 2508   "deep water 10"
   8:  Class    8: Number of pixels =  625   "white sands 5"
   9:  Class    9: Number of pixels = 2464   "deep water6"
  10:  Class   10: Number of pixels = 1856   "deep water5"
  11:  Class   11: Number of pixels = 2756   "deep_water3"
  12:  Class   12: Number of pixels = 2925   "deep water2"
  13:  Class   13: Number of pixels = 5700   "deep water"
  14:  Class   14: Number of pixels =   64   "poor mangrove"
  15:  Class   15: Number of pixels =  420   "mud82"
  16:  Class   16: Number of pixels =  180   "mud80"
  17:  Class   17: Number of pixels =  672   "white sands34"
  18:  Class   18: Number of pixels =  952   "muddyWater72"
  19:  Class   19: Number of pixels =  440   "mud70"
  20:  Class   20: Number of pixels =  120   "most likely mud65"
  21:  Class   21: Number of pixels = 3920   "very Muddy water64"
  22:  Class   22: Number of pixels = 3834   "whiteMud63"
  23:  Class   23: Number of pixels =   63   "whiteMud61"
  24:  Class   24: Number of pixels =   99   "mud60"
  25:  Class   25: Number of pixels =  717   "water51"
  26:  Class   26: Number of pixels = 1366   "water50"
  27:  Class   27: Number of pixels = 1294   "land53"
  28:  Class   28: Number of pixels =  653   "land52"
  29:  Class   29: Number of pixels =  203   "land51"
  30:  Class   30: Number of pixels =  588   "land50"
  31:  Class   31: Number of pixels =  846   "mud50"
  32:  Class   32: Number of pixels =  629   "mangrove51"
  33:  Class   33: Number of pixels =  612   "mangrove50"
  34:  Class   34: Number of pixels = 1055   "water41"
  35:  Class   35: Number of pixels = 1615   "water40"
  36:  Class   36: Number of pixels =  541   "land41"
  37:  Class   37: Number of pixels =  541   "land40"
  38:  Class   38: Number of pixels =  727   "mangrove40"
  39:  Class   39: Number of pixels = 2157   "mud40"
  40:  Class   40: Number of pixels =  192   "mangrove32"
  41:  Class   41: Number of pixels =  197   "mud32"
  42:  Class   42: Number of pixels =  193   "land31"
  43:  Class   43: Number of pixels =  283   "land30"
  44:  Class   44: Number of pixels =  203   "white mud30"
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 45:   Class   45: Number of pixels =  152   "mud30"
 46:   Class   46: Number of pixels =  115   "mangrove30"
 47:   Class   47: Number of pixels =  128   "very muddy water30"
 48:   Class   48: Number of pixels =  565   "water22"
 49:   Class   49: Number of pixels =  506   "water20"
 50:   Class   50: Number of pixels =  286   "land22"
 51:   Class   51: Number of pixels =  500   "land20"
 52:   Class   52: Number of pixels =   79   "light mud21"
 53:   Class   53: Number of pixels =  151   "mud20"
 54:   Class   54: Number of pixels =  178   "mangrove21"
 55:   Class   55: Number of pixels =  214   "mangrove20"
 56:   Class   56: Number of pixels =  249   "shallow water"
 57:   Class   57: Number of pixels = 4303   "water3"
 58:   Class   58: Number of pixels =  400   "water2"
 59:   Class   59: Number of pixels = 2173   "water"
 60:   Class   60: Number of pixels =  404   "vege land3"
 61:   Class   61: Number of pixels =  263   "bare land5"
 62:   Class   62: Number of pixels =  288   "bare land4"
 63:   Class   63: Number of pixels =  664   "bare land3"
 64:   Class   64: Number of pixels =  475   "mangrove5"
 65:   Class   65: Number of pixels =  568   "mangrove4"
 66:   Class   66: Number of pixels = 1421   "mud3"
 67:   Class   67: Number of pixels =  243   "grass land"
 68:   Class   68: Number of pixels =  136   "vege land"
 69:   Class   69: Number of pixels =  361   "bare land"
 70:   Class   70: Number of pixels =  387   "scree"
 71:   Class   71: Number of pixels =  204   "mangrove2"
 72:   Class   72: Number of pixels =  250   "mangrove"
 73:   Class   73: Number of pixels =  214   "mud2"
 74:   Class   74: Number of pixels =  330   "mud"
 75:   Class   75: Number of pixels =  170   "rainforest2"
 76:   Class   76: Number of pixels =  181   "rainforest"


Correlation matrix
    1.000      0.8805      0.8483      0.6894      0.5049      1.000
   0.8808      0.7217      0.5498       1.000      0.7699     0.6379
    1.000      0.5689       1.000

Pooled standard deviations       72922.0 df
    4.899       2.722       3.998       3.408       5.631

Between-classes ssq for each band
  0.3083E+08  0.1573E+08  0.5415E+08  0.6090E+08  0.2296E+09

Means - class by class
    97.66       29.71       23.56       14.92       10.93

    92.69       34.82       31.01       15.75       10.58

    87.80       30.89       30.17       30.60       10.81

    100.8       37.12       28.29       14.91       10.24

    98.85       30.64       24.19       15.65       10.62

    100.5       32.87       24.61       15.30       10.43
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90.29	27.30	23.19	15.07	10.35
190.3	98.21	149.9	132.6	229.1
115.5	40.79	25.56	10.24	6.367
100.1	29.86	22.79	13.91	11.05
124.8	43.18	29.76	16.45	13.65
100.2	28.63	23.59	15.36	12.60
99.40	28.86	22.79	14.68	11.83
104.3	46.58	54.58	61.62	69.56
121.4	57.09	77.68	63.08	77.58
115.7	52.52	67.78	58.19	93.17
179.2	88.59	127.4	108.1	193.5
105.9	44.92	50.72	22.63	8.036
107.4	45.75	56.63	46.69	64.98
107.7	48.13	61.08	51.67	73.15
109.2	48.75	61.89	41.14	7.300
165.1	81.94	117.0	100.9	193.3
133.8	66.24	96.44	87.43	169.0
116.1	53.03	71.07	60.85	87.70
112.6	47.31	47.49	14.87	7.346
110.8	43.93	35.42	12.22	7.251
117.2	49.08	65.18	64.67	125.9
90.61	36.92	48.16	55.50	94.56
102.2	44.76	62.48	60.89	127.6
98.01	42.15	55.82	68.39	111.9
119.3	53.24	65.90	54.10	39.25
82.08	29.32	27.83	63.48	32.65
84.34	29.83	28.60	60.40	29.89
113.7	47.11	40.72	12.15	6.718
108.7	42.15	30.26	10.95	6.737

90.35	37.08	49.41	62.47	109.2
104.4	47.65	68.64	70.94	133.8
79.96	28.74	27.09	63.88	30.79
114.6	52.15	63.95	54.45	20.05
93.75	38.20	39.44	72.22	48.36
117.4	53.79	71.31	60.57	95.27
99.52	42.81	62.59	63.48	117.6
98.79	43.21	57.57	71.06	115.3
143.6	71.79	104.0	90.34	181.1
119.5	57.41	79.77	66.34	90.16
86.77	32.07	31.90	67.14	34.17
123.5	60.83	82.49	48.35	13.52
114.5	52.51	52.21	18.38	10.85
112.7	49.23	44.62	18.42	11.32
96.80	38.88	49.20	58.40	99.72
102.4	46.11	67.84	78.15	130.1
139.2	67.81	101.2	93.47	175.2
113.7	49.97	61.90	54.15	82.42
91.22	35.00	34.39	67.78	36.77
91.85	36.63	35.29	80.76	38.68
121.6	52.19	46.64	12.65	6.908
116.5	44.28	29.66	10.72	6.742
113.4	48.00	44.05	13.92	8.537
116.3	47.19	36.13	11.11	6.941
93.06	40.93	55.35	68.35	116.2
93.66	40.34	53.02	63.10	124.5
86.55	35.95	45.64	58.28	95.16
86.31	34.01	44.40	45.37	90.99
76.29	28.10	26.64	63.33	33.68
78.27	28.30	26.51	65.65	34.71

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   129.8        58.65        73.95        60.93        84.70

   87.74        36.24        49.21        53.09        88.83

   79.82        31.76        39.68        60.98        75.28

   83.73        33.65        45.34        46.27        97.72

   93.00        41.98        60.40        76.93        117.8

   75.89        29.49        27.83        71.01        36.68

   74.27        27.98        26.08        69.46        32.74

   109.3        48.54        59.71        48.08        64.94

   108.0        47.73        58.42        47.79        61.47

   75.54        28.89        30.31        54.70        61.84

   77.93        30.27        32.10        63.79        74.44

Canonical roots
   147.7        34.00        28.81        7.198        3.770

Sum of roots =     221.42673

Product 1/(1+f(i)) =    0.16488592E-06

Canonical vectors - row by row
  0.1582       0.9226E-01 -0.7073E-01 -0.2348      -0.1162

  0.9254E-01   0.2017      0.1055E-01 -0.3264       0.1252

  0.2577      -0.2331     -0.4322      0.5812E-01   0.1457

  0.6355E-01   0.5103     -0.4226      0.2248     -0.3914E-01

  0.3243      -0.6962      0.1892      0.8346E-01 -0.5685E-01

Standardized canonical vectors
  0.7753       0.2511     -0.2828     -0.8003      -0.6541

  0.4534       0.5490      0.4219E-01  -1.112       0.7053

   1.263      -0.6345      -1.728       0.1981       0.8207

  0.3114        1.389      -1.690       0.7661      -0.2204

   1.589       -1.895       0.7562      0.2845      -0.3201

Canonical variate means
   11.75        10.76        6.169        12.69        11.85        12.39
   10.43       -29.16        17.09        12.43        16.17        11.76
   11.96       -5.605       -4.834       -6.126       -20.32        11.07
  -1.296       -3.463        6.884       -20.73       -19.69       -6.242
   14.49        15.37       -11.35       -9.676       -13.23       -13.61
   1.866       -4.975       -3.581        15.82        15.60       -13.13
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   -16.14       -5.189        3.313       -7.006       -6.800       -13.30
   -14.53       -20.25       -7.481       -5.302        6.401        13.70
    13.58       -9.872       -17.80       -21.16       -4.061       -4.954
   -8.038        16.98        17.12        15.00        16.78       -14.96
   -14.49       -10.95       -7.568       -6.003       -6.326       -3.423
   -9.037       -10.31       -9.067       -17.43       -8.174       -7.624
   -1.284       -1.006       -7.553       -10.77

    11.78        12.12        6.043        13.53        11.81        12.50
    10.49        24.44        16.64        12.37        16.91        11.86
    11.95        8.226        12.70        14.69        24.76        13.02
    12.67        12.62        8.075        24.33        19.40        13.31
    16.53        16.41        16.09        10.07        15.25        9.856
    9.735       -2.826       -1.845        17.33        16.15        9.646
    13.61       -3.509        6.542      -0.7141        14.63        12.52
    9.710        22.07        13.13       -2.797        10.49        17.10
    16.24        10.75        10.28        19.07        13.91       -1.649
   -5.251        19.01        17.37        17.17        17.90        9.703
    12.37        8.641        11.90       -3.441       -3.847        15.35
    9.749        3.740        12.15        7.365       -5.317       -5.777
    12.98        12.34        3.030        2.159

    10.52        4.825        5.742        7.462        10.33        10.00
    9.264        2.469        10.73        11.41        12.17        11.68
    11.61        6.158      -0.6150        5.239        4.950       -2.616
    4.732        3.804       -6.530        6.907        7.081        3.149
  -0.5908        4.780        12.68        10.93        11.03        11.59
   -1.286        10.74        10.29        2.402        6.725        12.82
    9.747        10.40       -4.166        9.453        4.287        9.451
    11.43        6.978      -0.6233E-01   9.981       -13.22       -2.644
    1.009        12.54        9.817        7.316        6.061        9.785
    10.21       0.7472        8.486        1.061        5.006        11.43
    13.63        11.45        11.02        10.19        10.99        3.706
    8.924        10.53        11.07        9.717        10.13        10.15
    3.301        3.181        11.82        13.71

    14.34        13.68        15.05        16.35        14.80        15.79
    12.85        19.70        19.41        14.66        20.55        13.97
    14.25        18.46        15.17        14.94        19.49        12.99
    14.19        14.35        14.62        17.97        14.59        14.65
    14.29        16.96        14.56        13.02        11.63        15.15
    17.53        21.41        20.90        16.52        17.83        13.55
    12.65        21.45        18.33        23.13        14.66        11.39
    15.46        15.04        14.56        22.15        14.37        15.72
    17.13        14.43        13.84        14.86        15.52        22.92
    26.26        17.22        19.61        15.89        18.42        14.22
    13.44        13.93        10.71        20.85        21.61        17.31
    11.73        15.27        9.905        14.49        22.64        22.31
    14.75        14.87        16.61        18.26

    16.07        12.39        14.61        12.86        16.00        15.04
    15.33        19.74        14.39        16.52        16.63        17.59
    17.00        12.92        15.18        13.35        18.54        14.10
    13.91        13.13        16.19        16.06        13.22        14.26
    13.40        12.67        14.39        12.05        11.63        12.34
    16.37        14.92        15.34        12.41        12.16        11.84
    11.97        14.63        16.38        14.55        13.74        12.92
    12.22        13.52        14.30        15.51        16.59        11.37
    11.62        12.83        13.07        14.93        13.63        15.29
```

```
15.50       12.58       13.08       12.38       12.23       11.25
10.51       11.13       11.33       13.59       14.20       15.53
11.92       12.09       10.62       12.08       13.19       13.48
13.27       13.33       11.17       11.37
```

```
     C V means - C V II  vs  C V I

   -31.000   -21.000   -11.000    -1.000     9.000    19.000
        +.........+.........+.........+.........+.........+
27.60 +                                                    +
      -                                                    -
      -                                                    -
      -  8       22                                        -
      -                                                    -
      -          44                                        -
      -                                                    -
      -           23                                       -
      -         52                                    56   -
      -                                            485117  -
15.60 +                   27                       4935 9  +
      -                 29     41 66                       -
      -              37        2453                4       -
      -                612  6945 12074           210       -
      -                       63                  1        -
      -             51 636  67         31   47   7         -
      -                    62                              -
      -             70          14          21             -
      -                                   39  3            -
      -                                                    -
 3.60 +                    68                              +
      -                       75                           -
      -                    76                              -
      -                                                    -
      -                       40                           -
      -                          533                       -
      -                        6382                        -
      -                        65                          -
      -                      772                           -
      -                                                    -
-8.40 +                                                    +
        +.........+.........+.........+.........+.........+
   -31.000   -21.000   -11.000    -1.000     9.000    19.000

abscissa - canonical variate I
ordinate - canonical variate II
```

```
        C V means - C V  3  vs  C V  1

     -31.000   -21.000   -11.000    -1.000     9.000    19.000
          +.........+.........+.........+.........+.........+
  15.00 +                                                    +
        -                                                    -
        -                61  76                              -
        -                 362750                        11   -
        -                629 66963                 110       -
        -                    687124833               6    9  -
        -             707 42    40454              7         -
        -                     67                         57  -
        -         5223                               4       -
        -          22             153                  35    -
   5.00 +                        16            3        59   +
        -          17            41   19           2   26    -
        -                        24 6674                     -
        -  8                                           34    -
        -                                            4958    -
        -                                               56   -
        -                       45 15                 25     -
        -                                31                  -
        -                                          1848      -
        -                                                    -
  -5.00 +                                  39                +
        -                                                    -
        -                                     21             -
        -                                                    -
        -                                                    -
        -                                                    -
        -                                                    -
        -                                                    -
        -                                                    -
        -                                     47             -
 -15.00 +                                                    +
          +.........+.........+.........+.........+.........+
     -31.000   -21.000   -11.000    -1.000     9.000    19.000

abscissa - canonical variate  1
ordinate - canonical variate  3
```

```
       C V means - C V  3  vs  C V  2

    -10.400    -2.400     5.600    13.600    21.600    29.600
         +.........+.........+.........+.........+.........+
 15.00 +                                                    +
       -                                                    -
       -               76           61                      -
       -                         350     211                -
       -                75     6260639  29                  -
       -     7716433     68      28  6    9                 -
       -         45440        70 5 74237                    -
       -                         67       57                -
       -                              4     523             -
       -                       14     53 35     44 22       -
  5.00 +                     3         16  59               +
       -                            19 4126         17      -
       -                            724 66                  -
       -                                  34        8       -
       -                                 498                -
       -                                    56              -
       -                            155  25                 -
       -                         31                         -
       -                             18   48                -
       -                                                    -
 -5.00 +                     39                             +
       -                                                    -
       -                       21                           -
       -                                                    -
       -                                                    -
       -                                                    -
       -                                                    -
       -                                                    -
       -                                                    -
       -                          47                        -
-15.00 +                                                    +
         +.........+.........+.........+.........+.........+
    -10.400    -2.400     5.600    13.600    21.600    29.600
```

abscissa - canonical variate 2
ordinate - canonical variate 3