A remote sensing survey of vegetation communities adjacent to Myall Lakes, NSW, Australia

Julia Yagüe & Pilar García
Complutense University, Department of Regional Geographical Analysis and Physical Geography, Madrid, Spain; jyague@ghis.ucm.es, pmgarcia@ghis.ucm.es

Keywords: multitemporal, NDVI, mapping

ABSTRACT: Myall lakes are an extensive series of coastal lagoons on the central coast of New South Wales, Eastern Australia. The Ramsar Convention and the status of National Park protect 44,612 ha. Other environmental legal figures are present in the area. To date, lagoons communicate with the sea following the lower Myall River onto Port Stephens Bay. A belt of sand dunes separates the lakes from the southern Pacific Ocean. The region has a humid temperate climate with average annual rainfall of 1300mm and mean monthly temperatures ranging from 17°C in winter to 27°C in summer. Changes in substrata and the complex variety of habitats within the sand dune systems favour botanic diversity and an intricate mosaic of vegetal associations, quite dependant on fire history, timber extraction and grazing clearing. Multitemporal remotely sensed imagery is analyzed to comprehend this scenario: aerial photographs (1981), Landsat TM (30.11.1993) and Landsat ETM+ (08.08.2001). Imagery analysis methods included image geocorrection and mosaicing, atmospheric filtering, radiometric enhancement, visual interpretation, vegetation index withdrawal, supervised classification and mapping. Fieldwork and species cataloguing preceded imagery analysis and classification; results showed direct relationship between plant associations and landforms. Spectral differences and NDVI values account for the following vegetation communities: (i) Fore dune associations of mat sand-binding species and woody bushes. (ii) Dry eucalypt forest over stabilized sand dunes, dune flats and high ridge lands, conformed by Blackbutt-Red Gum (Eucalyptus pilularis, Angophora costata) or Bloodwood-Red Gum (Eucalyptus gumifera, Angophora costata). (iv) Humid eucalypt forest, locally known as tree swamp. (v) Dry shrubby formations (vi) Humid shrubby formations and mangroves on swamps and bogs. (vii) Littoral rain forest sheltered in apt pockets and (viii) grazed areas.

1 MYALL LAKES IN GEOGRAPHICAL CONTEXT

The alternance of coastal dunes and swamps conforms a constant physiographic sequence along the coast of NSW, Australia. The natural plant communities of these wetlands have been severely altered since colonial days, especially in the extended Sydney interface. The Myall Lakes district, about 230 km north of the state’s capital, has a special interest and assets since the coastal vegetation has been very little disturbed. The lakes conform the only remaining example of large coastal brakish lake system on the NSW coast which has not been greatly modified by human activity (NSW NPWS 1984). The interconnected lakes produce an unusual environment where fresh and brakish waters mix. From north to south, these lakes are named thus: Wallis, Smith’s, Myall, Boolambbyte, Bomah-Broadwater and Port Stephens bay (Figure 1).

The aboriginal dwellers belonged to the Biripi and Worimi tribes, divided into a number of nurras or local groups, each occupying a definite locality within the tribal territory. Aborigines
were wandering hunters and gatherers who walked about their own territory in response to seasonal availability of food. Their presence was reported by Captain Cook in 1770 and by the five escaped convicts from the second fleet (1790-95). Colonial presence became permanent in 1816 with cedar getters and the establishment of the Australian Agricultural Company (1826), which subdivided the land in 1849 for private settlement and pastoral production, with settlers arriving from England to take up land grants there. Life followed even between the cultural groups until 1850 when conditions deteriorated to violent hostilities. Productive economy during the second half of the nineteenth century was focused on timber-getting which was closely followed by timber industries, ship building, farming, fishing and mining. Population growth was the main challenge during the first half of the twentieth century; since the 1950’s tourism has been the key element to fix population to the land and from 1960 to 1985 open sand mining contributed to the local economy in a remarkably way. The ecologic conservationist spirit developed in parallel to the point of achieving
A remote sensing survey of vegetation communities adjacent to Myall Lakes, NSW, Australia

the State’s recognition and legal protection of large areas of the Shire under the figure of National Park and others.

Combined geology, landforms, soils and weather lay down the supporting grounds for the distribution of vegetation communities. The dominant underlying geological structures are the folds sketched (W to E) by the Crawford-Givan anticline, the Myall syncline and the Bungwahl anticline that reshape the series of carboniferous age from N to 40º W (Atkinson et al, 1981). The main rock types are basically mudstone and sandstone, graywakes, shale limestone and volcanic series, which act as a key conforming element of the actual coastal shape. Mesozoic and tertiary series are basically non-existent in the study area. The coastal sedimentary forms gather the quaternary series, mainly gravel, sands, silt, clay together with other marine eolian and freshwater deposits (NSWDM, 1966). Most of these recent deposits rest upon the eroded and faulted carboniferous rocks. The thickness of the sand deposits varies up to 80 m.

The geomorphic progression of the Myall lakes is determined by two distinct beach ridge systems. Within the bedrock embayments of this coastal stretch several types of landforms can be recognized which are the product of fluvial, paludal lacustrine and estuarine processes during the late quaternary period (Thom, 1965). From south to north of the study area the following distinctive features can be identified: (i) stabilized sand dune ridges aligned parallel to the shore line, (ii) transgressive stabilized dunes that have mantled bed rock outcrops, (iii) sandbars enclosing partially or permanently the (iv) lagoons, (v) hard rock headlands and volcanic outcrops, (vi) back swamps and filled-in channels.

The region enjoys a humid temperate climate with average annual rainfall of 1300 mm and average temperature of 17ºC. Rainfall experiences a summer maximum while the dries months occur in late winter and spring (September-October). Thus, rainfall is somewhat seasonal though evenly distributed throughout the year; onshore breezes dominate the wetter summer months. Relative humidity does not fluctuate significantly from the yearly mean of 70%. NE and SE wind directions are dominant with occasional stronger southerlies, usually accompanying storms. In winter and spring, dry westerly winds usually prevail Mean monthly temperatures range from 17ºC in winter to 27ºC in summer with minimums of 3ºC and 15ºC respectively (Atkinson et al, 1976).

Soils on the deep siliceous sands are podsolts. Organic stained sands occur in the top A horizon; the A2 horizon is bleached and there is an iron organic and/or aluminium hard pan at variable depth (Carolin, 1971). These soils are highly permeable but may suffer from seasonal water logging. Disturbance of the vegetation cover makes these soils highly susceptible to both wind and water erosion. This is shown in the fact that improve pasture developments have low returns because of their very low fertility and poor water relations. Acid peat soils occur in some low laying swale areas. Volcanic outcrops that have not been mantled by Aeolian sands present red toughed earths with a gradational texture profile of clay loam at the surface or light clay at depth. Nutrients are abundant in these soils despite strong acidity. Natural fertility however declines markedly after intensive use. Hicks and Mason (1981) quote the following soil types for the area: shallow stony, brown duplex and brown coluvial soils, swamp and alluvial soils.

Changes in substrata and the complex variety of habitats within the sand dune systems favour botanic diversity in the area. The complex mosaic of vegetation communities depends, as well, on timber getting, fire history and depth to the water table. Osborn and Robertson (1939), Clough (1979), de Castro Lopo (1981) and Atkinson et al (1981) have undertaken thorough reconnaissance surveys of the vegetation in the Lakes District. Noy-Meir (1981) analyzed data on vegetation species presence or absence in the catchment area showing the most common land uses affecting vegetation species distribution. Coffey and Hollingsworth (1973) presented a detailed catalogue of species found in each community between Smith’s lake and Seals Rock. Eucalyptus pilularis-Angophora costata open forest communities dominate deep stable sands or dune flats south of Smith’s Lake, with a xeromorphic under-storey. The under-storey is dominated by Banksia serrata, Macrozamia communis and Peteridium esculentum. Composition and association of species depends partially on their position in the dune-swale topography (F1 Blackbutt-Angophora costata in the classification below). North of Smith’s lake (Pacific Palms and Booti Booti), the high ridge lands sustain the so called dry eucalypt forest in which the dominant species are Eucalyptus maculata,
Eucalyptus punctata and Eucalyptus propinqua, commonly known as Spotted gum and Grey gum, though the composition is quite variable. Eucalyptus amenooides (white mahogany) and Eucalyptus paniculata (ironbark) occur throughout though they are not dominant. Eucalyptus salignus (Sydney blue gum) and Eucalyptus tereticornis (forest red gum) are restricted to sheltered sites. The forest under-storey lacks a distinct shrub layer and the ground cover includes, among others, species such as Kangaroo grass, Bracken fern, Dusky pea, Myrtle wattle, Grass tree and others. Gillian and Gillian (1981) observed the landscape importance of this community for it occupies the major ridgelines, providing a visual backdrop for the beaches and urban areas. New grassland communities have resulted in areas where the forest has undergone clearance: lantana along with blandy grass (Imperata cylindrical) and kikuyu (Pennisetum clandestinum) (F2 Bloodwood-Angophora costata in the classification below). Swamp heath develops on low-lying flat land with permanently waterlogged soil. This community includes banksias (Banksia robur), Christmas bells (Blanfordia grandiflora) and crimson bottlebrush (Callistemon citrinus) among other species. This community is unique in local terms and, to date, it remains fairly undisturbed. (S2 Shrub swamp). Cabbage tree communities (Livistona australis) are common in the area; it cannot be considered rare but it does have local major significance for fruit eating birds and other wildlife. Fieldwork led to the in situ recognition and mapping of these associations as shown in Figure 2.

Figure 2. Vegetation associations.

2 MATERIAL AND METHODS

Fieldwork reconnaissance was taken further and contrasted against multitemporal and multi-seasonal remotely sensed data. The objective behind the spectral analysis of these images was to ascertain the capacity of Landsat to discriminate the intricate mosaic of botanical associations housed in the area, contrasting various classification algorithms and for both seasons, dry and humid. The imagery processed included colour aerial photographs (1984, scale: 1:18.000), a DTM (pixel size 90 m) and the following Landsat scenes:

<table>
<thead>
<tr>
<th>Sensor</th>
<th>Path/Row</th>
<th>Date</th>
<th>Season</th>
<th>Pixel Size</th>
<th>Geometric correction</th>
</tr>
</thead>
<tbody>
<tr>
<td>Landsat TM</td>
<td>089/082</td>
<td>30.11.1993</td>
<td>Summer</td>
<td>28,50 m</td>
<td>Projection.</td>
</tr>
<tr>
<td>Landsat ETM+</td>
<td>089/082</td>
<td>08.08.2001</td>
<td>Winter</td>
<td>14,250 m</td>
<td>UTM Zone 56.</td>
</tr>
<tr>
<td>Landsat ETM+</td>
<td>089/083</td>
<td>08.08.2001</td>
<td>Winter</td>
<td>14,250 m</td>
<td>Spheroid/Datum WGS 84</td>
</tr>
</tbody>
</table>
All imagery has been processed with Erdas Imagine 8.6 throughout. The early data preparation steps included (i) channel stack, (ii) geometric correction and orthorectification applying the Landsat geometric model which is derived by space resection based on colinearity equations. The elevation information is required in the model for removing relief displacement. (iii) mosaicing was applied to the winter images so as to cover the whole of the Great Lakes area, from Port Stephens in the South to Forster-Tuncurry by Wallis Lake in the North. Another data preparation step taken was (iv) filtering for haze reduction; for the TM multi-spectral images, the de-haze method is based on the Tasseled Cap transformation which yields a component that correlates with haze. This component is removed and the image is transformed back into RGB space. Radiometric enhancement was sought through (v) histogram equalization, a nonlinear contrast stretch that redistributes pixel values so that there is approximately the same number of pixels with each value within a range. Spectral enhancement involved (vi) band combinations for visual recognition and spectral signature sampling, (vii) withdrawal of NDVI and (viii) the NDVI image difference, highlighting seasonal and temporal changes in the vegetation communities. The difference image is the direct result of subtraction of the before NDVI image (1993) from the after NDVI image (2001). The outcome is a greyscale image composed of single band continuous data. Since change detection calculates change in brightness values over time, the image difference reflects that change in greyscale: whitish tones imply an NDVI increase between 1993 & 2001 while darker tones should be understood as a lost or lowering of the NDVI records by 2001. NDVI multitemporal data sets gather valuable information on the phenological characteristics of vegetal associations and provide the basis for cover mapping and the analysis of dynamic terrain processes; the multi-date structure increases classification accuracy when compared to single date land cover classifications. The final methodological process applied to the imagery has been (ix) the supervised classification of vegetation associations, limited to the narrow interface between the ocean and the lakes. The parametric classification decision rule chosen has been that of the minimum distance since the maximum likelihood rule gave very poor results.

3 RESULTS AND DISCUSSION

Imagery analysis reconfirms the complex and rich botanic kaleidoscope that furnishes the coastal fringe. The spectral visual analysis evidences the usefulness of the panchromatic band to enhance the underlying structural shapes (ETM+ images). The thermal bands particularly ease the reconnaissance of humid zones and vegetal associations. The use of the NIR channel highlights the photosynthetic activity but the contrast comes to its highest when combined with a thermal channel: in fact, the combination of NIR-thermal data shows the relation between the humid zones or available surface moisture and photosynthetic activity. Particularly showy band combinations were: RGB 3-5-6 (TM), which allowed a neat contrast between the two major eucalypt associations (i.e: Blackbutt-Angophora costata & Bloodwood-Angophora costata), discrimination of swamp limits and the hedges of quaternary sand dune accumulations as well as structural fault lineations. The combination RGB 5-4-8 (ETM+) sharpened the edges among swamp communities, especially between shrub and tree swamp. The combination RGB 6-4-8 (ETM+) allows an indirect discrimination of salinity levels through the thermal data provided by channel 6; the meeting of contrasted water salinity and temperatures is most striking in Wallis lake mouth and in Port Stephens.

The NDVI spectral enhancement yielded distinct seasonal values for most of the associations analysed as shown in Figures 3 and 4 and Table 1:

NDVI results were enhanced computing the NDVI difference image (Figure 5): since the subtracted
values belonged to a summer and a winter image, differences were both seasonal and multitemporal. The outcome image showed more coastal sediments in 2001 as well as an increment of NDVI values experienced by the restored vegetation cover of the former Bridge Hill Ridge open-air mineral exploitation (higher values, lighter colours). The newest vegetation on the mine site is well over ten years old and the whole site now exhibits the characteristics of an immature forest ecosystem. Other seasonal differences show how the inland eucalypt masses lower down the photosynthetic activity during the summer and raise it in winter. The wetter winter condition of swamps is shown in darker tones. The urban extension of Forster-Tuncurry in Wallis Lake also appears in dark colours, thus proving an increase of the urban lay out between 1993 and 2001 reflected in a net loss of NDVI.

The classification of the coastal fringe associations gave contrasted accuracy between the winter and the summer images (Figures 6 and 7). Conclusions are: (i) Winter spectral ranges are narrower and therefore spectral signature distances less independent than in summer; the summer image gave better classification results. (ii) The two main eucalypt associations are spectrally apart and more
Table 1

<table>
<thead>
<tr>
<th>Vegetation community</th>
<th>Summer Image 30.11.93</th>
<th>Winter image 08.08.01</th>
</tr>
</thead>
<tbody>
<tr>
<td>Blackbutt - Angophora Costata</td>
<td>0.400 - 0.490</td>
<td>0.410 - 0.490</td>
</tr>
<tr>
<td>Bloodwood - Angophora Costata</td>
<td>0.530 - 0.570</td>
<td>0.610 - 0.640</td>
</tr>
<tr>
<td>Tree swamp</td>
<td>0.440 - 0.460</td>
<td>0.370 - 0.380</td>
</tr>
<tr>
<td>Shrub swamp</td>
<td>0.310 - 0.350</td>
<td>0.190 - 0.300</td>
</tr>
<tr>
<td>Cabbage Tree forest</td>
<td>0.640 - 0.720</td>
<td>0.450 - 0.490</td>
</tr>
<tr>
<td>Rain Forest</td>
<td>0.570 - 0.620</td>
<td>0.590 - 0.650</td>
</tr>
<tr>
<td>Foredune Communities</td>
<td>0.400 - 0.460</td>
<td>0.180 - 0.390</td>
</tr>
<tr>
<td>Foredune revegetation in progress.</td>
<td>0.130 - 0.400</td>
<td>0.340 - 0.440</td>
</tr>
</tbody>
</table>

Figure 4. NDVI ETM 2001.
individualised in winter; however, their individual winter classification is blurred by the spectral response of the cabbage tree association. (iii) The summer image neatly singled out the eucalypt associations, the shrub swamp, the cabbage tree forest and the rain forest; (iv) tree swamps are partially confused with the blackbut association and the fore dune class is also expanded to unpaved roads and to the re-vegetated sand mine. (v) North of Smith’s lake, the human impact is greater producing land cover disruptions which difficult the classification. (vi) The topography exhibits sharp aspect contrasts along the coastline with very different soil moisture conditions: windward slopes absorb the humidity of sea breezes while leeward slopes experience high evapo-transpiration rates due to high summer temperatures. This contrast misleads the classification, assigning a tree swamp cover to the windward side instead of the dry bloodwood-Angophora costata association. (vii) The rainforest pockets and the cabbage tree patches sheltered in the leeward fore dune are very well depicted although their size might be modest.
Figure 6. Summer classification of vegetation communities.
Figure 7. Winter classification of vegetation communities.

REFERENCES


Coffey & Hollingsworth (1973) Environmental impact study and statement of proposed sand mining operation at Bridge Hill NSW. Mineral Deposits Ltd. Brisbane.