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An initial assessment of changes to the *Melaleuca* distribution on a selected area of the Magela floodplain using aerial photography

J Riley & J Lowry

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supervising scientist

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Photo by M Saynor

J Riley & J Lowry

Note: an unpublished paper based on this IR was produced by J Riley, J Lowry and M Finlayson, and presented by M Finlayson at the 11th Australasian Remote Sensing and Photogrammetry Association Conference in Brisbane, 3–5 September 2002.

Supervising Scientist

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1 Background / Introduction

Concerns have periodically been raised about the possible encroachment of *Melaleuca* spp. into previously unoccupied areas in Kakadu National Park. Recent examples were ABC-Radio and TV news bulletins of the 6th and 7th of September 2001 (ABC 2001), respectively, which linked recent research findings on the spread of *Melaleuca* in Papua New Guinea, and the Mary River floodplain in the Northern Territory with the concern that woody vegetation communities — as represented by *Melaleuca* spp. — may change the wildlife habitats and environments in the wetland areas of Kakadu National Park.

While studies have been undertaken in the past which looked at the distribution of *Melaleuca* in selected areas of Kakadu (eg Williams 1984), there is presently not an established method for monitoring the spread or distribution of *Melaleuca* within Park boundaries.

The temporal analysis of remotely sensed imagery– such as aerial photographs – provide one means by which vegetation cover may be mapped and monitored. Williams (1984) used aerial photography from 1950 and 1975 to perform a temporal analysis of changes to *Melaleuca* distribution on the Magela floodplain. His study found that within the 25-year time period between air photos, while there been no increase in the area occupied by *Melaleuca*, 38 % of the forested area had suffered a significant decrease in tree density.

In response to the concerns recently aired, and after consultation with members of Parks Australia North, it was decided that ***eriss*** would initiate a preliminary analysis of changes in *melaleuca* distribution on a section of the Magela floodplain (figure 1).

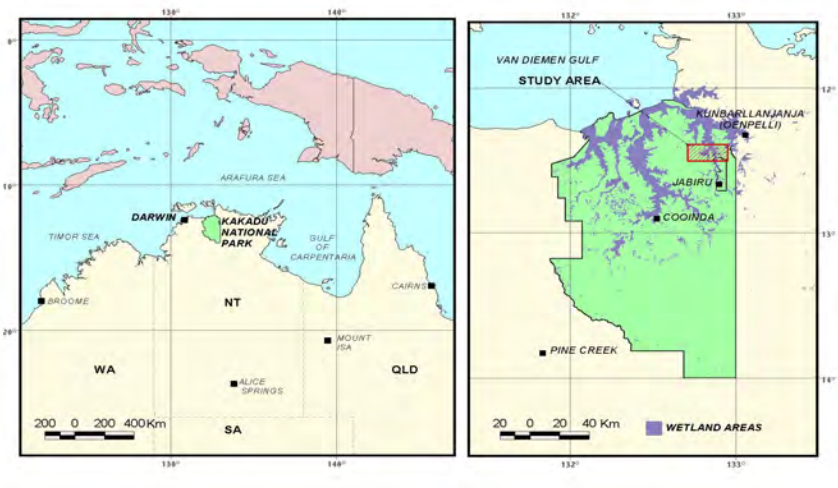

Figure 1 Location of study area within Kakadu National Park (Data sourced from AUSLIG 1:250 000 topographic data and ESRI ArcWorld digital datasets)

The area of interest for this study includes an area of the Magela floodplain that had been previously studied by Williams, enabling comparisons of *Melaleuca* density and distribution, to be made for this portion of floodplain for the period between 1950 and 1996. Figure 2 shows the extent of the Williams study area and the extent of the current study area.

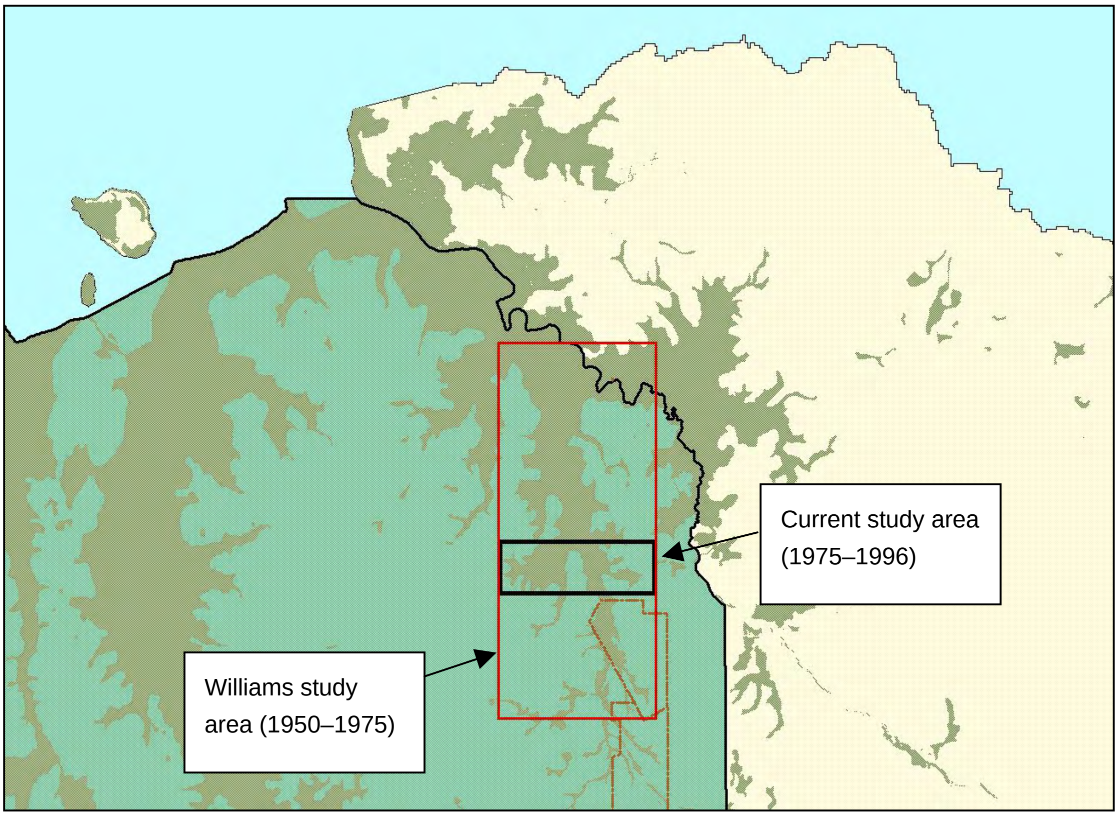

Figure 2 Extent of existing and earlier studies

2 Aims

The aims of this project were three-fold:

1. To establish what change in *Melaleuca* distribution had occurred on a section of the Magela floodplain within Kakadu National Park. This was undertaken through the use of remote sensing and geographic information systems (GIS) software to analyse changes detected from aerial photographs flown in 1975 and 1996;

2. To review the methodology applied by Williams in identifying the extent of *Melaleuca*, and compare the estimates of *Melaleuca* distribution for 1975 using the techniques described by Williams, and the techniques developed for this project using remote sensing and GIS technologies; and

3. To develop and document a cost-effective methodology for monitoring *Melaleuca* distribution from aerial photography.

3 Methodology

The methodology developed for this project can be broken into four main phases:

1. Photo acquisition and identification
2. Data capture –scanning and rectification of photos
3. Mosaicing of photographs
4. Analysis and interpretation of *Melaleuca* density and distribution

3.1 Photo acquisition

The first phase of the project involved the identification of aerial photographs of the Magela floodplain. It is recognised that possible sources of aerial photography could include Parks Australia North, and the Northern Territory Government. However, for the purposes of this exercise, only existing photographs of Kakadu National Park held by ***eriss*** were utilised.

The key focus of this study was a temporal analysis of changes in *Melaleuca* distribution. Consequently, an important element of this phase was the identification of those photographs of the Magela floodplain which would be comparable to those used in the study by Williams (1984) — specifically photographs flown in 1950 and 1975, plus any photographs of this area taken more recently. Other factors that were considered included the scale of the photography, and its format — either black and white, or colour. Taking these factors into account significantly reduced the number of aerial photographs held by ***eriss***, which would be of use in this project. The photos found which matched the criteria described earlier are listed in table 1.

Table 1 Photographs of Magela floodplain corresponding to Williams study area held by *eriss*

Scale	Year	Photo number	Colour/ black and white
1:25,000	1975	3119, 3121, 3123, 3125	Colour
1:25,000	1975	3119, 3120, 3121, 3122, 3123, 3124, 3125, 3126	Black and white
1:25,0000	1996	Run 1, photos 85-89;	Colour
		Run 2, photos 69-84;	
		Run3, photos 51-68;	
		Run 4, photos 32-50;	
		Run 5, photos 12-31	

It was noted that the black and white 1975 photographic coverage held by ***eriss*** covers extensive areas of the Magela floodplain, including the area of interest for this study.

Black and white photographs flown over the Magela floodplain to a scale of 1:50 000 in the 1950s are held by ***eriss***. However, these did not cover the same area as the 1975 photographs. Runs 5 and 6 are available with some missing photographs but run 7 are required to mirror the 1975 coverage.

To match the coverage of the 4 colour photographs from 1975 required a selection of 9 x 1996 photographs from 5 runs.

It will be possible to compare further black and white 1975 areas with the 1996 coverage and with some areas of the 1950, 1:50 000 coverage.

It was noted that the 1975 colour photographs had minimal overlap with each other whereas the 1975 black and white photographs had approximately 60% overlap. The 1996 photographs had approximately 60% overlap.

3.2 Data capture — scanning

A Hewlett Packard 7200 colour A4 scanner was utilised to scan the aerial photographs. An early challenge was that while the scanning bed possessed a width of 210 mm, he selected photographs had a width of 229 mm. This meant that it was not possible to scan each photographic print in its entirety.

The photographs were positioned on the scanner with the most northerly edge of each photograph aligned with the top of the scanner with the result that all scanned photographs have their most northerly side at the top of the scanned image. The top edge does not however reflect true north.

The width of the photographs and the inset nature of the scanning surface resulted in one side edge being elevated at the time of scanning. The size of the scanning surface dictated that an edge of the photograph is not scanned.

The black and white photographs were printed on a stiff light card photographic paper and the surface of each photograph is concave. The stiff nature of the black and white photographs together with the concave nature of the photographs resulted in an uneven contact with the scanning surface of the scanner resulting in possible intermittent distortion. The stiff nature of the card may also result in some light entering the scanning surface due to the inability of the cover to lay absolutely flat on the photograph. There will also be a degree of error associated with the fact that the photograph is wider than the surface of the scanner as the entire surface of the photograph is not able to lay flat on the scanning bed but remains slightly distant from it on one side.

The narrow nature of the scanning bed dictated that the scanning process could not accommodate all borders and fiducial markings. As all markings could not be accommodated the remainder of the markings became redundant. The area scanned was reduced to the approximate edge of the photograph itself and so most fiducial markings are absent from the scanned images.

A preferred scanning option would be to use a larger scanning bed so that each photograph could be placed entirely flat on the surface with the scan bed cover able to be pressed down firmly so that all surfaces were in direct contact with the scanning bed. The larger scanning surface would also serve to keep any outside light out of the scanning area. An added advantage would be that all fiducial markings would be able to be incorporated in to the scan. Whilst this may not be important for the current study it may be of use for future uses of the scanned photographs.

Test scans were carried out on the black and white photographs to ascertain whether to scan them in Grayscale or in True colour. The true colour scan resulted in an almost sepia representation of the black and white image. The Grayscale scan delivered a far crisper detail and stronger black and white colouring. As a result, colour scans of black and white photographs were not used for this project.

Test scans were carried out at scan resolutions of 200, 300, 600 and 1000 dots per inch (dpi). Images were saved in a variety of formats, including *.bmp, *.tiff and *.jpeg to determine the format from where least data was lost. One colour photograph scanned at 1000dpi and saved as a jpeg file took 6 minutes of actually scanning time and resulted in a 9 MB file. An image scanned at 600dpi and saved as a .bmp file resulted in a very clear image but a file size of 72 megabytes (MB). The most appropriate scan resolution was determined to be 600dpi (K Pfitzner, pers com) and the file format most appropriate was considered to be jpeg (jfif). At 600dpi the resolution represented is approximately 1-metre pixels. Consequently, all photographs used in this project have been scanned at 600dpi and saved in jpeg format, together with their appropriate metadata.

In total, the following images were scanned:

78 x 1996 colour photographs (nine in area of interest; 69 of broader Magela floodplain, for possible future reference)

4 x 1975 colour photographs

6 x 1976 black and white photographs

3.2.1 Metadata

A Microsoft Excel spreadsheet was used to create a metadatabase for recording the ancillary information associated with each of the photographs. The type of information recorded for the photographs in each of the years is shown in table 2.

Table 2 Types of metadata recorded for photographs used in mosaic

1975 black and white photographs	1975 colour photographs	1996 (colour) photographs
Photo number	Photo number	Photograph identification number
Assigned name consisting of Run Number, Photograph Number and year of photograph	Assigned name consisting of Run Number, Photograph Number and year of photograph	Assigned name consisting of Run Number, Photograph Number and year of photograph
Time of acquisition of photograph	Time of acquisition of photograph	Time of acquisition of photograph
Definition of bw for black and white designation	Definition of col for colour designation	Camera settings, heights etc

To mosaic the images in ERDAS Imagine, each image needed to be registered to a base layer. The base layer was created in the ArcView® environment. Several coverages representing drainage features, waterbodies and roads were extracted from AUSLIG 1:250 000 digital topographic datasets, and clipped to the same size as the area of interest to enable accurate registration, and to check the detail and accuracy of the rectified images. A 1:100 000 digital topographic map, map number 5473 was also subset to cover the area, using the Image Analysis extension in ArcView.

The process required to subset an image in Image Analysis is simply to set the View display to reflect the area of the subset image. The image properties were set to 'same as display' and the 'save image as' option chosen to create a new image that was subset to the display parameters.

Each photographic image was imported into ERDAS Imagine and saved as an Imagine (*.img) format file. These, together with their Imagine header format (*.rrd) files have been saved to CD2 (for 1975 photos) and CD13 and CD14 (for 1996 photos). The complete list of CD's and their contents are listed in Appendix 1.

To rectify each of the study area images a model of the projection parameters was created. This model is used in photographic rectification to eliminate the possibility of inconsistency. The model chosen was initially based on the Australian Geodetic Datum 1966 (AGD66); as described later, this was subsequently changed to the Geocentric Datum of Australia 1994 (GDA94).

Because the exact position of each photograph on the scanning bed varied slightly, it was necessary to create individual Areas-of-Interest (AOI) for each scanned photographic image as part of the rectification process. Those images selected to be rectified were subset to remove all extraneous edges and markings, such as fiducial marks that had been captured during the scanning phase.

While it would have been preferable to subset each of the images to a neat rectangle, this would have resulted in the reduction of the overlap areas that may be needed. The beginning and ending pixel for each area of actual photograph were different between images. They were dependent on the direction of the run, which dictated the expanse of border. One problem that was discovered during the subsetting process was that the working directory for ERDAS Imagine (the default is c:\temp) requires plenty of free disk space. If there is insufficient disk, an error message of 'not enough room' is returned. Aside from ensuring that there is adequate space in the working directory, and deleting unnecessary files, trial and error during this exercise found that if the file to be subset was not loaded into a viewer and simply handled as a file name and the AOI was also used as a saved file and not active in a viewer, the problem did not arise. Consequently, the remainder of the images were subset in this way.

Each image was loaded and individually registered to the 1:100 000 AGD66 digital topographic map 5473. Points from the image that are recognisable on the map are linked to each other. These are known as Ground Control Points (GCP) and a minimum of 12–15 are generally required for each image. It is of paramount importance that these points are as accurate as possible so the images align when mosaiced and that they truly reflect the geographic references assigned to them. In this project, an average of 24 points per image was used. These points were spread as widely as possible with attention being paid to locating some near edges and corners where possible.

A simple test to determine if sufficient GCP points had been added, was to check the RMS error when new points had been added, and to check if the point prediction tool allocates points to the correct position. Once sufficient GCP points had been added, the image can be warped to fit the base map and have the datum added to its header file.

3.2.2 Image registration — 1st attempt

The first attempt at registering the scanned images of the aerial photographs utilised a raster image of the 1:100 000 map sheet 5473. This dataset was already projected into Australian Map Grid Zone 53, using the AGD66 datum. A number of problems ensued with the use of this dataset which ultimately meant that the attempts to register photographs to this base were unsatisfactory. As explained in the succeeding sections, the photographic images were ultimately rectified to a 1:50 000 base using the GDA94 datum.

3.2.2.1 Initial problems encountered with using 1:100 000 raster map as base for rectification

The first problem encountered was the scale and accuracy of the 1:100 000 raster map used for registering photographs on the Magela floodplain. Simply, it was inadequate, as the position and depiction of features on the map — such as roads, and the position of river channels — did not match those on the photographs. A further limiting factor was that those features on the map were themselves compiled in 1971 – earlier than any of the photographs being used.

In some images there are large areas of water. Within these essentially featureless areas on the photos, it is extremely difficult to add GCPs, which could be used to associate the photo, with the base map layer. Consequently, it was necessary to approximate the position of some point locations on the photographs. This reduced the overall accuracy of the rectified image.

A mosaic was successfully created from six black and white aerial photographs taken in 1975 in Imagine (figure 3). Each photograph was individually rectified to the 1:100 000 topographic raster map 5473. Little distortion occurred at the overlap areas, resulting in the photos fitting together well, and forming the mosaic.

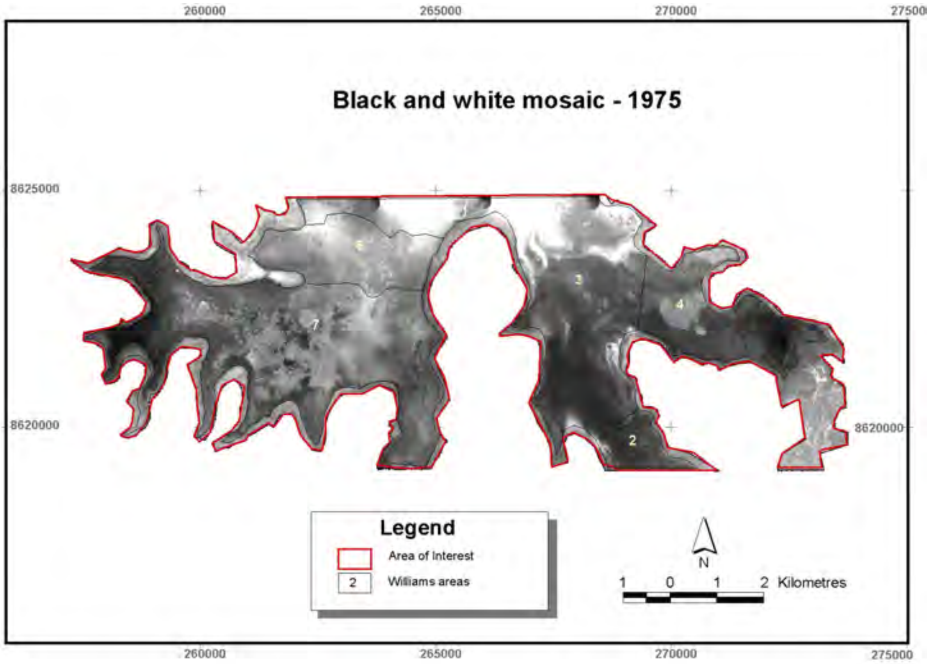

Figure 3 Mosaic of black and white photographs flown 1975

The corresponding four colour 1975 images were individually rectified to the same base (the 1:100 000 raster map) and then mosaiced in Imagine (figure 4). The resulting mosaic appeared fine at the join lines between the individual images but when this image was displayed on top of the black and white image there was a visibly discernable error of approximately 5 to 10 metres in some areas between the same features on the two mosaics.

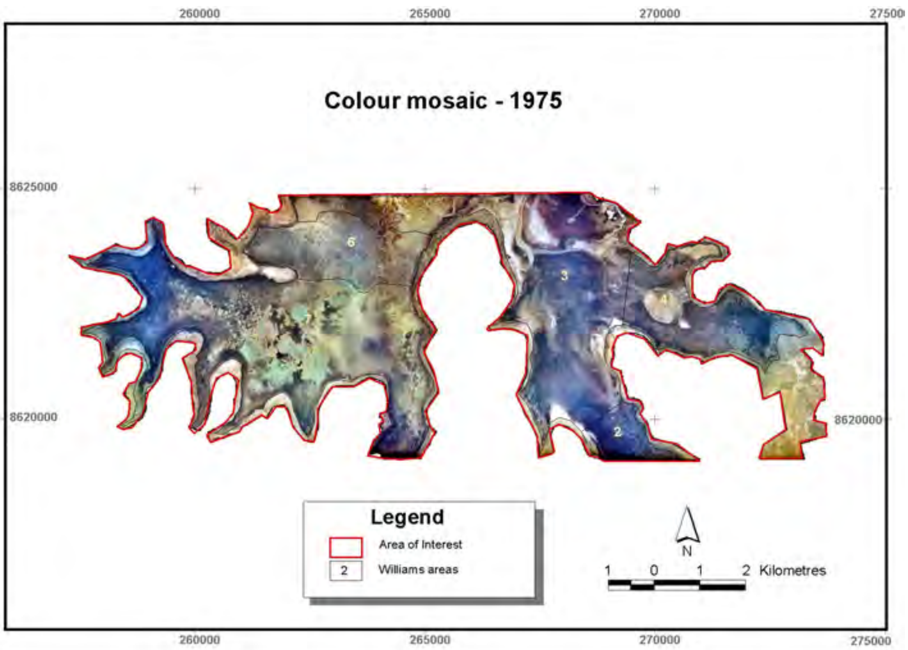

Figure 4 Mosaic of colour photographs flown 1975

The nine images of the 1996 coverage were individually rectified to the same base as the 1975 photos. An additional problem for the rectification of the 1996 images was that the position of some landform, drainage and infrastructure features had changed to some degree from the 1:100 000 raster map which was being used as the base for registration.

The 1996 images were mosaiced with care taken to display the most consistent colouring across the mosaic. Several different mosaicing techniques were tested, and listed in table 3.

Table 3 Mosaicing techniques

Test Number	Tests performed
1	Image matching for all images
2	Image matching No cutline Average
3	No matching No cutline Feather
4	Image matching No cutline Feather
5	Image matching No cutline Feather
6	No image matching Feather
7	No image matching Average

A further attempt was made at producing a mosaic with no cutline, stitching and no image matching. In addition, pixel values of 0 were ignored. Whilst this produced a mosaic in which there were some joins that were not a perfect there was a good overall level of fit. However, the colour throughout the image was quite varied. The colour matching option in the mosaicing function of Imagine did not appear to make a great deal of difference in the continuity of colour. The images mosaiced with the colour matching option were blurred in the overlap area by the process (figure 5).

Several different stretches were tried on the resultant mosaic to try and even out the colour variation. The variation within the 9 images appears to be too great to stretch the mosaic successfully. The variation is within each image as well as between each image. A degree of this variation may be attributable to the narrow scanner. There may also be a contribution from the sun angle at the time that the photographs were taken. They were taken after 6pm in mid June so there will be a large shadow effect. The necessity to select photographs from different runs will add a level of inconsistency because of this oblique sun angle.

It should be noted that once each mosaic had been created, the mosaic was subset to the study area reflecting the floodplain areas previously mapped by Williams (1984).

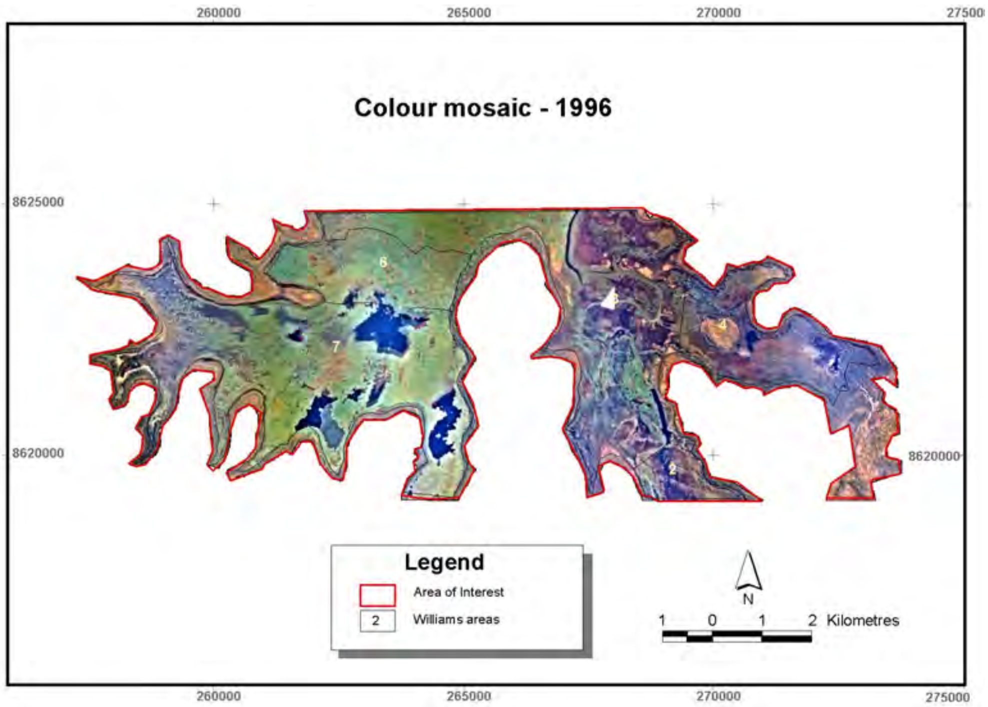

Figure 5 Mosaic of nine colour photographs 1996

3.2.2.2 Classification

The 1996 image was classified in Imagine with an unsupervised classification to 25 and also 100 classes with .990 covergence parameter with 10 iterations and a skip factor of 1, ignoring zero.

The classified image was analysed but it was not possible to assign accurate classes, as the variety of colouring within and between the images resulted in a broad range of classes representing *Melaleuca*. Of particular concern was that some of the classes were 'mixed', and represented *Melaleuca* as well as other species.

Overall, it was not possible to establish clear classes for *Melaleuca*. Commission and omission errors were high as judged by comparison to the appropriate aerial photographs. The classified image was also compared with a macrophytic vegetation map of the Magela floodplain (Finlayson et al 1989). When the map was scanned and compared to the classified image there was little correlation between the two.

Because of the problems outlined earlier, the idea of identifying *Melaleuca* communities through the classification of the mosaiced images was not pursued in this project.

As classification of the mosaics was not an option for an accurate representation of the presence of *Melaleuca*, an ArcView shapefile was created to represent the distribution of *Melaleuca* communities within the area shown for each of the mosaics.

Each shapefile created contained point features that usually represented individual trees. Where the canopy of *Melaleuca* was too dense to discern individual trees, a thick coverage of points was applied to the area.

The shapefiles of *Melaleuca* created from the 1976 colour mosaic and from the 1996 mosaic were overlaid on top of each other in order to determine the changes in distribution and density of the *Melaleuca*. Unfortunately it became evident that there was a discrepancy in the registration of the 2 mosaics. After close inspection it was decided to abandon the 1976 shape file coverage and the corresponding 1976 colour mosaic and to reregister and mosaic the 1976 images. This was carried out and a new shapefile (*1976_Melealeuca_2.shp*) created.

Verification of selected areas of *Melaleuca* was carried out by inspecting the applicable photographs stereoscopically. Further verification was provided by consulting with staff familiar with the Magela floodplain, and with the appearance of *Melaleuca* trees on aerial photographs. It is important to note that this project did not entail any independent ground truthing to verify the distribution of *Melaleuca* identified on the mosaics.

Creating mosaics of images for 1975 from black and white and colour photographs enabled *Melaleuca* distribution to be cross-referenced between the, assisting with the identification of the extent of the distribution.

Inspection of the 1996 mosaic and its associated shape file revealed that areas previously thought to be added shadow detail produced by the scanning process were in fact superimposed offset images. It was thought that this had resulted from the layers of individual images not lining up accurately in areas in the mosaic. In some areas — such as the central waterbodies — the errors were considerable. There are several possible reasons for this discrepancy including:

- The nadir and off nadir difference between the centres and edges of the photographs
- The fact that one edge of each photograph was not flat on the scanner
- The inaccuracy of registration due to the general nature of the 100K topographic map
- The unavailability of locatable points in water coverage areas of the images.

It was decided that these mosaics whilst reasonably suitable for purely visual display were not sufficiently accurate to be used as base images for further analysis or studies.

Several attempts had been made to improve the accuracy of the rectification and mosaicing. The final attempts at improving the accuracy of the products in ERDAS Imagine produced mosaics *1975_col2_studyarea and 1996_studyarea* . Both mosaics were projected into AMG Zone 53, using the AGD66 datum.

It was found that the accuracy of registration on the images could be improved by importing the images into another image processing program, ENVI. The ENVIsoftware enabled each image to be registered to each other on a pixel to pixel basis through their overlaps. In contrast, the registration process in Imagine involved each image being registered to a base map, a process that was susceptible to approximation of placement of control points and images. Using the ENVI software enabled each image would to be rectified to the exact same area on another image, forming a mosaic. The entire mosaic would then be registered to a topographic map.

3.3 Mosaicing — ENVI

Each of the 1996 images was opened in ENVI in Imagine .img format. When opened in ENVI the images had a large black surround together with some fiducial markings. Each image was subset to a rectangular shape to remove both the border and the fiducial markings. Care was taken to retain a large part of the overlap area. To achieve this the Pixel locator was activated and the sample and line numbers of the appropriate start and finish points were located and the file subset to this area. The images were then registered to each other and warped. In the registration process one image remains as the base and the second image is to be registered or warped to the first. The images were registered in a sequential order that limited the number of times that an individual image would be warped.

The advantage of ENVI in the registration process is that accuracy of point to point referencing could be reduced to approximately one pixel in any direction therefore within <± 1 metre.

As pairs of images were registered they were mosaiced together giving due consideration to the colouring of each image so that the more consistent colouring could be retained in the eventual mosaic. Options were limited in the mosaicing process. The images were stitched with the stitched area 35 pixels wide. Zero was ignored in the statistics. The pairs of images were then registered to each other, warped and mosaiced once again.

Problems were encountered with the registration of the most easterly pair of photos (photo numbers 22 and 23 from run 5). The RMS error was quite high and many extra points were added to reduce this high error reading. When the 2 images were mosaiced together they were quite concave on the eastern side. The problems appear to arise from photo 23. It may be that there was some aircraft movement when the photograph was taken. These images were reregistered and warped again to 2nd degree, producing a much more acceptable mosaic. When overlaid onto image 22 the overlap is well matched. Image 23 contributes just a small area to the eventual study area and the area of 23 to be used is from the Western side of the image. This warped file is quite acceptable in those areas. The 2nd degree warped number 23 image was kept.

The pairs of images were mosaiced together from the centre of the eventual mosaic to the outside edge. As this process was under way it was discovered that the central pair would need to be warped twice. This would result in this central pair of images being warped more times than the surrounding images. This process was abandoned and the pairs were mosaiced together to make groups of 4. In one instance, an individual image (run2, photo 87) was warped to the edge of its nearest 4 image mosaic. The resultant 5 image mosaic and the remaining 4 image mosaics were then registered to each other and mosaiced to form one single mosaic.

The 1975 black and white images were then also registered to each other, warped and mosaiced. During this process, it was found that it was necessary to scan an extra photo number (photo 3120) to ensure overlap between photos 3119 and 3121. This photograph had been discarded in the selection process as 3119 and 3121 had a sufficient degree of overlap for the Imagine rectification and mosaicing process. However, the degree of overlap between the two photographs was insufficient for use in the ENVI rectification process. Photo 3120 itself is of poor quality, with several white splotches on it and was not of sufficient quality to include in the mosaic. Consequently, the photo was instead used as the base image (underneath the other images) in the mosaicing process, thereby ensuring that it will not be visible at all.

To increase the accuracy of the registration process, the area of interest on the Magela floodplain was scanned at 300dpi from a copy of a 1:50 000 topographic map of the area, Cannon Hill and saved as a jpeg file. When this file was loaded into ENVI it had a 30 m pixel size. The scanned 1:50 000 topographic map was registered to a hard copy of itself with approximately 30 GCP points, and projected into the Map Grid of Australia Zone 53, using the Geocentric Datum of Australia 1994. This resulted in a large RMS error, which may be attributed to the manner in which the map was scanned (not perfectly square on the scanning surface), which in turn reduced the ability to select the exact crossover point of geographic line markings on the map.

When the image was warped and loaded for the purpose of registering the mosaics, it was discovered that the 30 m pixel size was too coarse to allow for accurate registration. The map was rescanned at 300dpi and subsequently at 600dpi with efforts being made to ensure that the map was square on the scanning bed.

However, the 600dpi scan still resulted in an automatic recognition of a 30 m pixel size in ENVI. The 600dpi scan was discarded as it provided no extra information and was a very large file. The new ‘squared off’ 300dpi coverage was displayed and the header information was altered so that the image would display at a 1 metre resolution. The image was registered with 28 GCPs, which produced an RMS of 0.92, indicating that the image was satisfactorily rectified to a 1 m resolution.

The process of registering the mosaics to the scanned 1:50 000 topographic map was begun in ENVI, but because the mosaic to be registered was quite large and the process was visually quite difficult on a single screen, the registration process was transferred to Imagine. The mosaics and the digital topographic coverage were saved as Imagine .lan files so that they could be opened in Imagine. Once they were loaded in Imagine, they were saved as .img files. The registration process of mosaic to map was carried out in Imagine using 64 GCP points and with an RMS error reading of 23.2. At a 1 m pixel size this equates to a 23.2 m overall error. This error reading was assessed to be acceptable considering the scope of the mosaic and the error acknowledged on the topographic map of ± 25 m.

The new mosaics created from the 1975 black and white photographs and the 1996 colour photographs were then clipped to the study area. The original area of interest (AOI) file was loaded and minor adjustments were made to the AOI. The mosaics were subset using this AOI.

The result was unexpected. When the AOI was displayed on top of the image it represented the correct area. When the AOI was used to subset the same image it offset by 205 m. The process was repeated with the same result. A new study area AOI was created and used without problem. The reason for the offset remains unknown. It would appear as if it was a datum change error but the AOI displayed on both the AGD66 and the WGS84 image in the correct position. The error was apparent only when subsetting was carried out.

The 1996 mosaic and the 1975 black and white mosaic had been evaluated and found to be very close to each other in registration. There was far less difference between the 1996 mosaic and the 1975 mosaic created in ENVI than between the mosaics of the same images created in Imagine.

The 1975 colour mosaic appeared to be mosaiced well in Imagine. To judge whether this mosaic needed to be reconstructed in ENVI it was reprojected to GDA94 so that it could be displayed in a layered view with the 1975 black and white mosaic created in ENVI and evaluated for accuracy.

It was found that the 1975 colour image was reasonable but there was room for improvement. The creation of this new mosaic has not as yet occurred.

As described earlier, the new mosaics were created in GDA94 and the shape files representing *Melaleuca* were created on top of images registered to AGD66. The shapefiles need to be re-aligned to GDA94.

The properties of the shape files were inspected and it was found that whilst they were created from an AGD66 base image, the shape file did not retain these projection properties. Using the ArcView Projection Utility, the projection properties of the shape files were assigned. New shape files were then created through the Projection Utility which were projected into the MGA Zone 53 of the GDA94 datum.

3.4 Analysis

For analysis purposes it was decided that the original AGD66 mosaics would be used as the *Melaleuca* coverages had been derived from these mosaics.

Williams (1984) divided his study area into a total of fourteen sub-areas (or 'strata'). Time constraints on the size of the study meant that only 5 of these sub-areas fell either wholly or partially within the boundaries of the current study. Table 3 identifies the sub-areas created by Williams that form the basis for this study, and lists the comparable areas in each. Within the limits of the available photography, these sub-areas were replicated within the current study to enable comparison of gains and losses of *Melaleuca* density within each sub-area (figure 6).

Table 4 Comparison of areas studied

Sub-area / stratum	Area–Williams (km^2)	Area – current study (km^2)
2	16.3	1.4
3	27.5	13.3
4	4.2	4.2
6	4.6	4.6
7	14.8	14.8
TOTAL AREA	67.4*	41.3

Note Total area studied by Williams (1984), for all 14 sub-areas was 175.5 km2

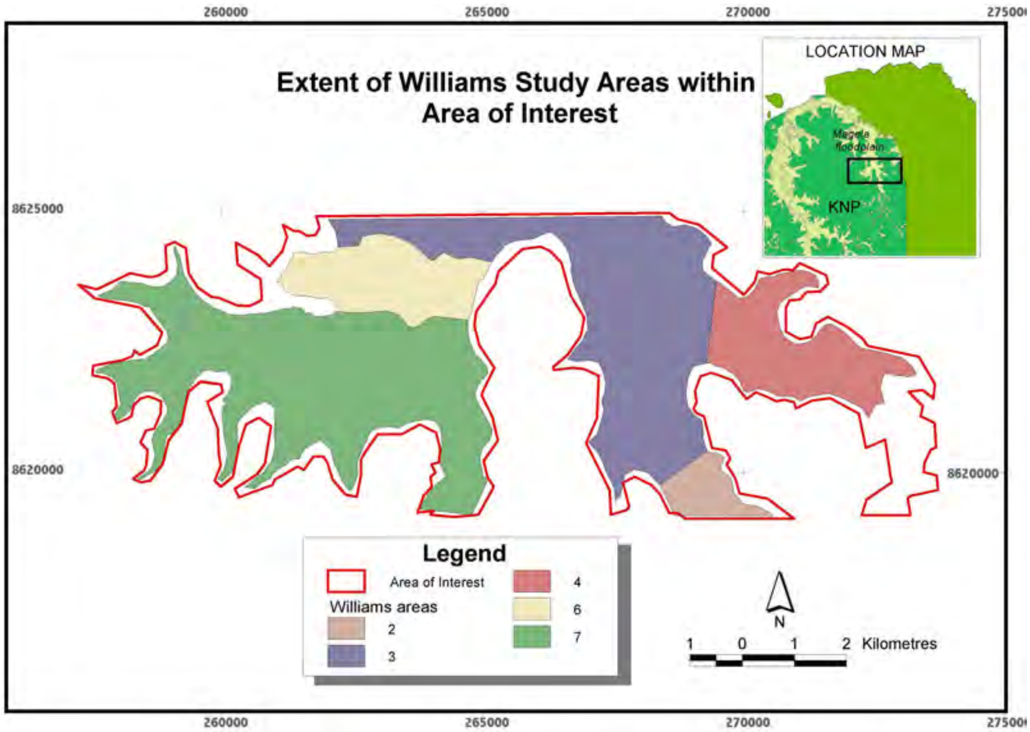

Figure 6 Extent of Williams (1984) study areas within area of interest

The main species of *Melaleuca* found in the Magela floodplain area are *M. viridflora*, *M. cajuputi*, and *M. leucadendron* (Williams 1979). These species show disparate growth forms varying from tall trees to straggly shrubs (Dunlop 1995, Holliday 1989). The diameter of, and density of, canopy cover also varies with species. A key assumption of this study was that all woody vegetation within the study area belonged to the genus *Melaleuca*.

The identification of *Melaleuca* was based on the visual interpretation of the mosaiced images, with each visible tree added as a point feature to the shape file representing the occurrence of *Melaleuca* trees. In some instances, particularly where dense occurrences of trees were observed, it was not possible to record an individual point for each individual tree. In those situations, points were used to represent groupings of trees.

The calculation of *Melaleuca* density followed the methodology described by Williams (1984) as closely as possible. This involved placing a minimum of 10 circular cells of varying diameter within each study sub-area (figure 7). The number of trees that occurred within them was counted (table 5), and the tree density in each cell calculated by dividing the number of trees by the area of the cell. The median density for the sub-area was calculated, and used for comparison with density values calculated for other sub-areas. The use of the ArcView desktop GIS system enhanced the accuracy and application of this process, through the ability to 'clip' trees into particular sample cells, calculate both the number of trees in a cell plus the area of the individual cells and thence to rapidly calculate median density values for the sub-areas.

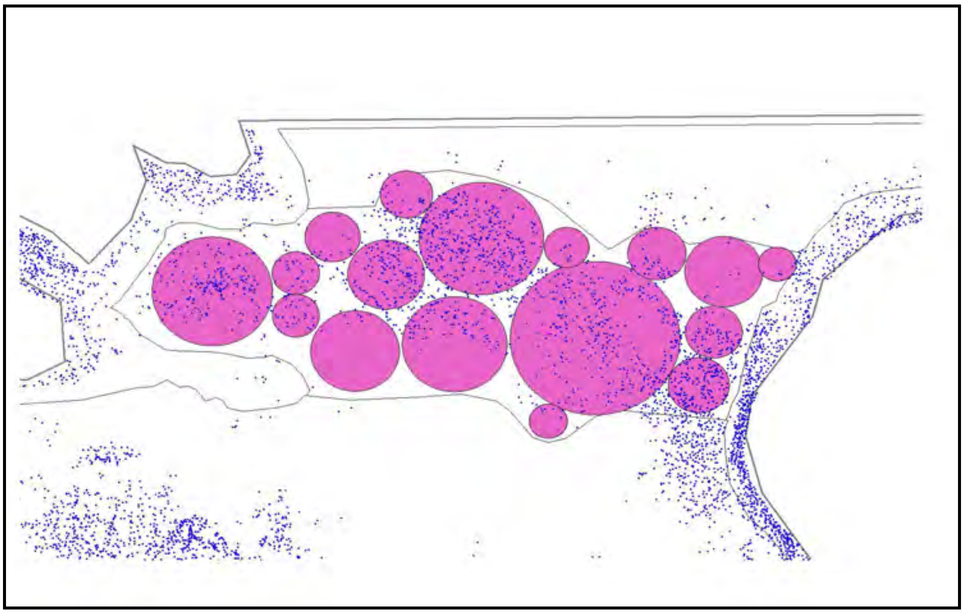

Figure 7 Sample cells used for calculating tree density in sub-area 6 of study

Table 5 Number of trees counted in each sub-area studied

Year	Sub-area 2*	Sub-area 3*	Sub-area 4	Sub-area 6	Sub-area 7	Total
1975	1886	2545	11238	5447	10317	31433
1996	819	1404	6989	1797	13695	24704
Change	-1067	-1141	-4249	-3650	+3378	-6729

* These areas do not cover the full extent of the area used in the study by Williams (1984)

4 Preliminary results

The distribution of the *Melaleuca* across the study area in 1975 and in 1996 is shown in figure 8. The number of trees found in each sub-area is listed in table 5. From this table, it can be seen that there has been a net decline in the number of trees in the study area as a whole, and with one exception (sub-area 7 — see figure 9), in each of the sub-areas as well.

Using the methodology described in the preceding section, density calculations were undertaken for the datasets representing *Melaleuca* distribution in 1975 and 1996. The overall total density of *Melaleuca* in 1975 was calculated as 764 trees/km^2, whilst for 1996 the density was calculated as 601 trees/km^2. This represents a decline in density of approximately 21%, over a 21-year period.

It is important to recognise that these density values are not uniform across the study area, with some sub-areas experiencing extensive clumping of trees (increased density) and others with very scattered distributions.

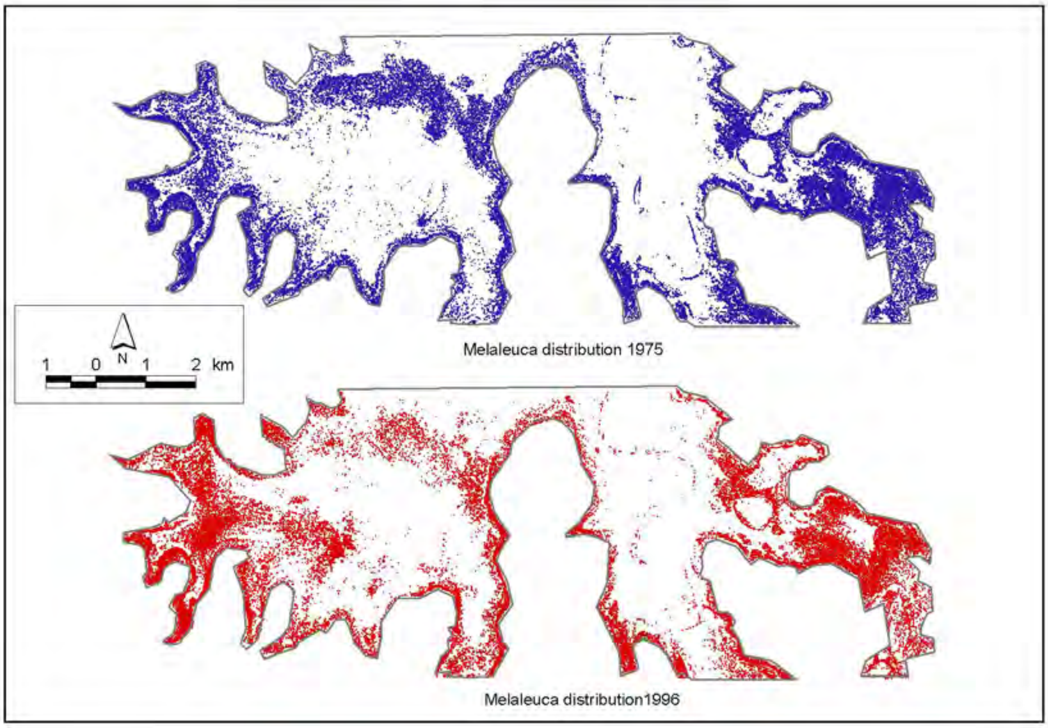

Figure 8 Distribution of *Melaleuca* identified in photographic mosaics compiled for 1975 and 1996

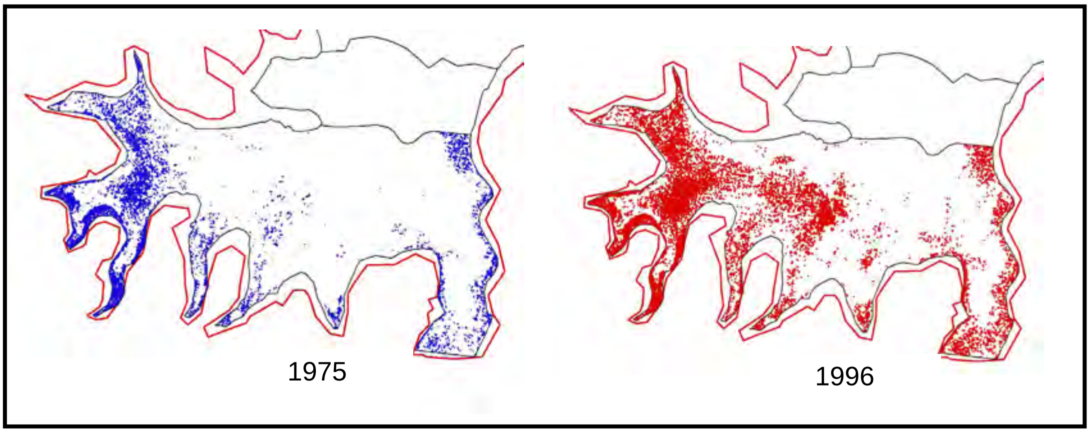

Figure 9 Changes in tree count in sub-area 7

In order to be able to compare the current study with that of Williams (1984), a similar methodology was adopted to obtain median tree densities in each sub-area in the study (table 6).

Table 6 Median densities of *Melaleuca* in sub-areas of study area

Year	Sub-area 2*	Sub-area 3*	Sub-area 4	Sub-area 6	Sub-area 7
1975	1314	180	2600	1484	1144
1996	627	50	1733	325	963
Change	*-687*	*-130*	*-867*	*-1159*	*-181*

* These areas do not cover the full extent of the area used in the study by Williams (1984)

The decline in overall tree density is reinforced when the median densities of the individual sub-areas are calculated. Again, it must be noted that this decline is not uniformly expressed across the study area, with some sub-areas actually experiencing increases in tree density. Sub-area 6 shows, proportionately, the greatest decrease in tree density. The changes observed in the sub-areas are illustrated in figure 10. Conversely, sub-area 7 shows proportionately the lowest decline in median density.

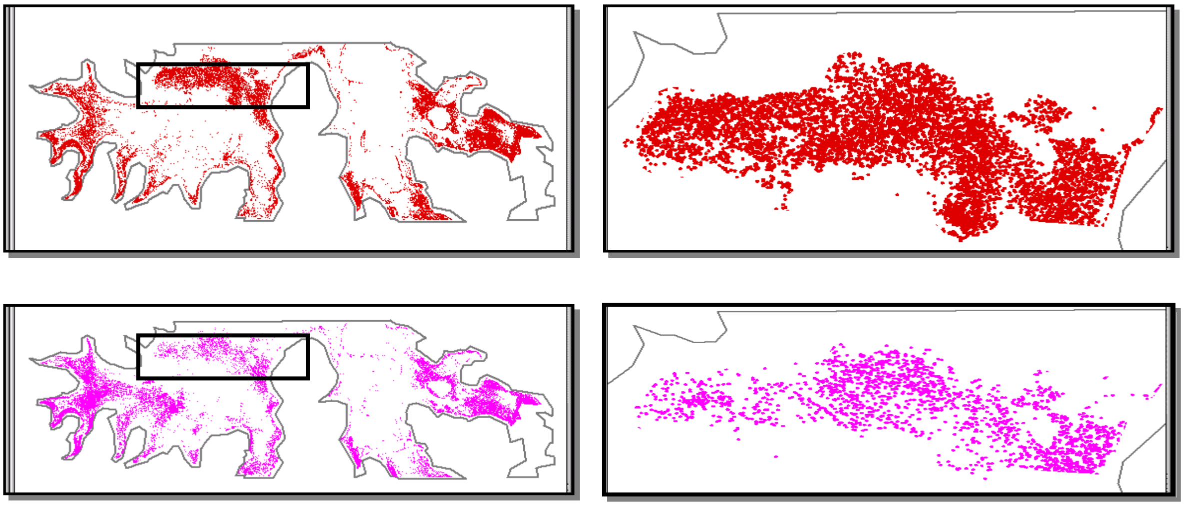

Figure 10 Change in *melaleuca* density in sub-area 6, 1975–1996

The relatively small area, and time periods used in this study means that the results found in this study may not be readily extrapolated out across the Magela floodplain. Further, additional work is required to correlate the changes in distribution and density observed in this study with environmental processes that may have contributed to those changes.

5 Discussion

Analysis of the mosaiced aerial photographs from 1975 and 1996, and associated shapefiles identified a number of changes in the *Melaleuca* visible in the photographs. As listed in table 5, there was an overall reduction (by approximately 21 %) in the total number of trees visible on the floodplain, between 1975 and 1996. However, this reduction was not uniform across the study area, with one sub-area (area 7) actually recording an increase in tree count.

A 21% decrease was also observed in the overall density of *Melaleuca* trees between 1975 and 1996, both in the study area as a whole, and within each of the sub-areas in the study.

As has been noted earlier, Williams (1984) undertook a study of changes in *Melaleuca* distribution between 1950 and 1975, using aerial photography. Insufficient information is provided in his paper to enable the methodology applied to his studies to be replicated precisely. Distribution of *Melaleuca* was described in terms of the number of trees observed in a number of circular plots within a particular study area. It was stated by Williams (1984) that the size of the plots varied within and between study areas, as did the number of study plots. Unfortunately, the number and size of the plots used in each of the study areas was not described or recorded in the paper. Without this information, it is not possible to readily identify the actual areal extent of *Melaleuca* distribution or any change in distribution since that time.

The relatively small, localised nature of the area, used in this study means that the results may not be readily extrapolated across the Magela floodplain. Further, additional work is required to correlate the changes in distribution and density observed in this study with environmental processes that may have contributed to those changes.

The results of this project show that it is possible to undertake desktop evaluation of *Melaleuca* density within a wetland habitat to discern trends in colonisation.

5.1 Comparison with earlier work

Williams (1984) undertook a study of changes in Melaleuca distribution between 1950 and 1976, using aerial photography. Insufficient information is provided in the paper to enable the methodology applied to his studies to be precisely replicated. Distribution of *Melaleuca* was described in terms of the proportion of canopy cover observed in a number of circular plots within a particular study area. It was stated that the size of the plots varied within and between study areas, as did the number of study plots. Unfortunately, the number and size of the plots used in the study areas was not described or recorded in the paper. Without this information, it is not possible to readily identify the actual areal extent of *Melaleuca* distribution. Further, the number of trees within each sample plot was merely estimated, as opposed to being actually counted.

To enable comparison of results for tree density measurements from the 1975 photography, the 5-point scale developed by Williams (1984) was adopted. The scale was divided into the following increments:

1 0–150 trees/ km^2

2 151–600 trees/ km^2

3 601–1100 trees/ km^2

4 1101–1600 trees/ km^2

5 More than 1601 trees/ km^2 (closed canopy)

Using this scale, the results from Williams (1984) for the 1975 aerial photographs is compared with the results of the 1975 photographs in the current study (table 7).

Table 7 Comparison of densities of *Melaleuca* in 1975

Study	Sub-area 2	Sub-area 3	Sub-area 4	Sub-area 6	Sub-area 7
Williams	2	1	3	4	1
Current	4	2	5	4	4

A comparison of results shows that the current study calculated the density of *Melaleuca* to be greater in almost every sub-area, with the exception of sub-area 6.

A significance difference appears in the estimates of *Melaleuca* density from the 1975 aerial photographs. This difference may be attributable to a number of factors, including

- the different areas used in the study. Sub-areas 2 and 3 in particular in this study did not encompass the same area as in the earlier study.

- the improvements in determining densities measurements using precise areas / shapes , generated in a GIS. The earlier study involved a manual assembly of aerial photographs into a mosaic, which was manually overlaid by an acetate overlay containing the sample circles used in each sub area.

Williams (1984) reported an overall decline in the density of *Melaleuca* on the floodplain between 1950 and 1975. This study, while not able to corroborate the densities found by Williams (1984) in 1975, indicates that the density of *Melaleuca* has continued to decline. In the earlier study, a number of factors that may have influenced the distribution of the *Melaleuca* were identified. These include the fire regimes in the surrounding landscape, and the presence of feral animals, particularly buffalo. As the latter have been removed from the Magela floodplain, it is postulated that the changes have occurred as a consequence of fire, although other influences, such as greater periods of inundation in the 1990s compared with the 1980s may also be implicated (CM Finlayson, pers com). Further analysis is required to determine which factor(s) were most responsible.

6 Future research and recommendations

The primary objective of this project was to identify change in the distribution of *Melaleuca* on a selected portion of the Magela floodplain. In undertaking this task, this project has created a dataset which may be applied to other wetland studies on the Magela floodplain, particularly those related to landscape/habitat mapping.

This study has identified the continuing decline in *Melaleuca* density on this section of the Magela floodplain. An area of future research could be to identify and investigate those factors that may contribute to the decline in *Melaleuca* density.

The acquisition of an A3-sized scanner, to capture any further aerial photographs would assist the data capture process, and largely eliminate the problems associated with scanning images on an A4 scanner identified earlier in this report.

The use of tree-counting software would enhance any further tree-density studies that may occur.

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Appendix 1 CD Listing and description

Note: Some files are titled 1976. These titles refer to 1975 photographs / images.

1. Magela air photos. 1976 –col, b/white, metadata, jpeg, scanned 600dpi.

    Southern area of Magela floodplain. 1975 coverage, both colour and black and white photographs scanned at 600dpi and saved in jpeg (jfif) format.

    3119, 3121, 3122, 3123, 3124, 3125 black and white

    3119, 3121, 3123, 3125 colour.

    Metadata for photographs.

2. Magela air photos. 1976 Area 1,.img, .rrd, black and white , colour.

    Scanned photographs as above saved as Imagine format files with associated header files.

3. Zip: Magela F'pl. 1975. Rectified.img. rect_1975_3119_3121

    Zipped file of all black and white and colour images numbered 3119- 3121 that have been rectified to agd 66 1:100K digital topographic coverage in Imagine.

4. Zip: Magela F'pl. 1975. Rectified.img. rect_1975_3122_3125

    Zipped file of all black and white and colour images numbered 3122- 3125 that have been rectified to agd 66 1:100K digital topographic coverage in Imagine.

5. Magela F'p 1975.img. 1975_bw_studyarea. 1975_col2_studyarea. Agd66

    1975 mosaic of 6 black and white photographs rectified to agd 66 and clipped to the study area. 1975 mosaic of the 4 colour photographs rectified to agd 66 and clipped to the study area.

    The 1975 colour mosaic is the image upon which the Melaleuca shape file was created.

6. Magela F'p. 1975_7 photo mosaic_bw, 1975_colour.

    Imagine format, .img and .rrd files

    2nd generation mosaics created in ENVI and registered in Imagine. These are more accurately registered but are not the mosaics upon which the *Melaleuca* shape files were created.

7. ENVI 1975 Magela photos. Warped files, gccs

    GCC files, 3121 (b/w, col), 3122 (bw), 3123 (b/w, col), 3124 (bw), 2125 (b/w, col), 1976 _7 photo, 1976 to 1996.

    Warped files, 3119, 21 to 20, 22 and 23 to 19, 20 and 21, 23 to 22, 24,25 to 22,23, 25 to 24, 1975 colour to 1975 black and white.

8. ENVI 1975 Magela Air Photos

    Mosaics   3124_3125 +3122_3123
    3119_20_21 + 3122_3123

    Mosaic of (3124 and 3125) added to base mosaic of (3122 and 3123)
    Mosaic of (3119 and 3120 and3121) added to base mosaic of (3122 and 3123)
    1975 7 photo mosaic, gcc points.

9. 1975 Air Photos. 1975_bw_wgs 84 [7 photo mosaic], 1975_colour_wgs 84 [4 photo mosaic]

    Mosaics developed in Envi on a photograph to photograph registration process and then registered to 1:50K digital topographic coverage in Imagine.

10. Magela Floodplain Area 1 1975, 1996 gcp points, ref, input files Imagine format.

11. ENVI 1:50K Cannon Hill topo. L/Right WGS 84 1 metre reln. Cannon Hill 300 dpi.

    ENVI format. Lower right portion of the 1:50K Cannon Hill topographic coverage scanned at 300 dpi jpeg format. Also same coverage at Envi format displayed at 1 metre resolution.

12. Magela Air Photos. 1996 col jpeg, metadata, scanned 600dpi.

    78 x 1996 colour photographs of the Magela floodplain area scanned at 600dpi and saved in jpeg format. Metadata file for photographs.

13. Magela Air Photos, 1 of 2, Area 1, 1996, .img, .rrd, 01_87, 02_77,78, 03_ 60,61, 04_039,039.

    1 of 2 cd's containing 1996 scanned photographs as above saved as Imagine format files with associated header files.

14. Magela Air Photos, 2 of 2, Area 1, 1996, .img, .rrd, 05_022,023.

    Second of 2 cd's containing scanned photographs as above saved as Imagine format files with associated header files.

15. 1996 Magela f'p .zip, rectified photos, input, ref files.

    Rect_input_ret_1996_runs 1_3

    Envi format registration files – input and reference together with associated warped or rectified images from study area runs 1 to 3.

16. 1996 Magela f'p .zip, rectified photos, input, ref files.

    Rect_input_ret_1996_runs 4, 5

    Envi format registration files – input and reference together with associated warped or rectified images from study area runs 4 and 5.

17. Magela F'plain, 1996_ study area (agd66), .img, .rrd

    Imagine format mosaic in agd 66, clipped to the study area.

    This is the 1996 image that the Melaleuca shape file was created on.

18. ENVI: 1996 Magela air Photos. Mosaics 23+22_39+38,

    87+78_77+60_61, gcp points.

    ENVI format mosaics. Mosaic 23 (base image) and 22 (top image) mosaiced to mosaic 39 (base image) and 38 (top image).

    ENVI format mosaics. Image 87 mosaiced to – {[mosaic 78 (base image) and 77 (top image)] base image, mosaiced to mosaic [60 (base image) and 61 (top image)] top image}.

    Associated gcp points

19. ENVI: 1996 Magela Air Photos. Major warped files.

    Mosaic [{39 (baseimage) +38 (top image)} + mosaic {22 (base image) + 23 (top image)}] mosaiced to [{87 (base image) + (mosaic of 78 (base image)} + 77 (top image)) mosaiced to {60 (base image) +61(top image)}]

    Mosaic [{(87 (base image)) + {78 (base image) + 77 (top image)} to mosaic of {60 (base image + 61 (top image)}]

20. 1996_9photo mosaic, Magela floodplain, ENVI format 1:25K, 600 dpi.

    This is the well registered, 9 photo unclipped mosaic 1:25,000 scale, each photo scanned at 600dpi.

    This mosaic has not been registered to a base map and has no geographic coordinates.

21. Magela Floodplain 1996_wgs84_study area, study area (clipped).

    Imagine format .img, rrd files

22. Whole: 1996_mosaic_wgs 84.zip. Magela floodplain mosaic 9 photo.

    This is the well registered, 9 photo unclipped mosaic 1:25,000 scale, each photo scanned at 600dpi.

    This mosaic has been registered to a base map and is in Imagine format (.img and .rrd files).

23. Magela: Melaleuca study, shape files.

    All shape files used for the project. Current as at 01 Feb 2002.

Appendix 2 Glossary of Terms

AGD66 – Australian Geodetic Datum 1966

AMG – Australian Map Grid

AOI – Area of Interest

GCP – Ground Control Point

GDA94 – Geocentric Datum of Australia 1994

MGA – Map Grid of Australia

RMS – Root Mean Square