# A guide to mapping *Mimosa pigra* in the Northern Territory, Australia

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***Abstract***

**Managers require information on the location, extent, density and biological characteristics of mimosa, *Mimosa pigra* L., to plan control and mitigation programs. Since the 1980s, numerous techniques have been used to map mimosa in the Northern Territory. This paper describes the methods and makes suggestions on mapping priorities. No single method is ideal. A combination of methods is necessary to most efficiently obtain data on mimosa distribution for management. The interpretation of satellite imagery has not been successful at mapping mimosa due to the variation in environments across its range. The detection of small mimosa populations is a key requirement in implementing the Mimosa Strategic Plan for Australia. Small infestations are most reliably detected by field or aerial surveys and the location recorded with a global positioning system device. A limitation of analysing the results of these surveys together in a geographic information system is the variation in the descriptive information obtained and the manner in which it is categorised. Regional monitoring programs comparing a series of satellite images over time offer a potentially useful overview of mimosa condition or trend, but this is only possible after models have been developed and refined by many years of monitoring field sites and comparing these to results from satellite image interpretation. The value of small-scale mapping to provide an overview of mimosa populations and their management has not been realised. Regional mimosa status mapping with a combination of existing digital data, supplemented with expert knowledge, is a technique that could yield a suite of useful maps for managing mimosa. This method should be tested.**

***Keywords***: mapping techniques, weed management, remote sensing.

## Introduction

Many techniques have been used to collect mimosa, *Mimosa pigra* L., distribution data, either by field surveys or remote sensing (Schultz 1987, Fitzpatrick 1989, Cook *et al.* 1996, Menges *et al.* 1996, Lyons 1999, Thorp and Lynch 2000, Parsons and Cuthbertson 2001). Pitt and Miller (1988) published the most recent review of techniques for mapping mimosa.

This paper aims to document mapping techniques either used or developed in the Northern Territory (NT), Australia up to 2001. Some factors specific to the NT that dictate mapping approaches include the large and relatively inaccessible area of potential mimosa habitat that requires survey. However, methods presented in this paper would have relevance to the mapping of mimosa in other places.

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## Map scale

Before presenting mapping techniques in the next section of this paper, it is important to explain the principle of map scale. An understanding of this principle is essential to interpreting a map and selecting a mapping technique. Map scale is defined as the ratio between map distance to earth distance (Anon. 2002). On a 1:100,000 map, 1 cm on the map is equivalent to 1 cm × 100,000 (1 km) distance in the field.

Terms that are frequently used to describe scale are "large" and "small". Large-scale maps cover a small area like house block and small-scale maps cover a large area like the Top End of the NT. Comparing two different scale maps, the larger scale map will depict the same feature larger than on the smaller scale map. For example, a 25 m by 25 m pool would appear as a square 5 × 5 mm in size on a 1:5,000 map but on a 1:100,000 map it would barely be seen.

The scale of mapping determines the detail that plant situations in the field are recorded. Table 1 gives the minimum width for delineating a discrete parcel for different scales of mapping. The minimum width is used as a guide for mapping. For example, when mapping in the field to a scale of 1:50,000 and using points to represent the infestation, then the points should be at least 150 m apart. If using an enclosed area (polygon) to represent the infestation the longest axis of the polygon should be at least 150 m.

Mapping is a representation of the population at the desired scale. Unless a very scattered population, mimosa plants and clumps will rarely arrange themselves to neatly form mapping units. With knowledge of the target scale and the minimum width, the mapping team can break up the field population into polygons or points that best represent the population at the desired scale. Generalising the population in this way is an efficient use of resources to obtain the data.

The scale at which data are collected limits the scale at which the data can be presented on a map. The rule is that data can only be presented on a map of the same or coarser scale than the acquisition scale. For example 1:50,000 data can be presented on a 1:100,000 map, but 1:100,000 data should not be displayed on a 1:50,000 map. There are some exceptions to this rule, particularly where there is an absence of data at finer scales. The NT cadastre data (acquired at 1:250,000) is tolerated on larger scale maps for this reason.

## Mapping techniques

In this section mapping techniques are presented for small- and large-scale mapping.

### Representation of weed distribution across the NT at a small scale

Small-scale maps of weed distribution for the whole of Australia or the NT typically fit on one A4 page. Mapping approaches at this scale are distinguished by the framework used for assessment and the description of density.

A rapid assessment and presentation of the Australian distribution of most weeds was achieved by Parsons and Cuthbertson (2001) by requesting State and Territory agencies to assign presence or absence for each weed on each 1:100,000 map sheet on the continent. These sheets form a grid of cells each half a degree of latitude in height and half a degree of longitude in width. Thorp and Lynch (2000) presented maps of signif-

**Table 1.** Examples of map scales and the smallest area feature that can be represented on each.

| Map extent | Scale of survey product or unit boundary data[a] | Minimum width of mapping units; a discrete parcel can be narrower than this if it is longer than this[a] | Examples of products from mapping vegetation at this scale |
|---|---|---|---|
| Northern Territory | 1:1 million<br>1:500,000<br>1:250,000 | 3,000 m<br>1,500 m<br>750 m | Vegetation map of the Northern Territory |
| Region | 1:100,000 | 300 m | Land unit surveys: Mary River Catchment<br>Litchfield Station<br>Barkly Tablelands |
| Catchment/property | 1:50,000 | 150 m | Land unit survey of the Daly River |
| Property | 1:25,000 | 75 m | Mangroves in Darwin harbour,<br>Mary River reserves weed survey |
| | 1:10,000 | 30 m | |
| | 1:5,000 | 15 m | Engineering works |

[a] From Speight (1990).

icant weeds in Australia using a grid of the same cell size but unfortunately offset from the 1:100,000 map grid.

Although the first two studies described distribution by just presence and absence, Thorp and Lynch (2000) further defined presence in each cell with one of the following classes:

- low – scattered plants with no heavy concentrations
- medium – scattered patches with isolated plants interspersed
- high – dense infestations in which animal/plant production or desired vegetation/biodiversity aspects are seriously diminished or limited. This class is inclusive of the lower classes.

Although each grid cell in this assessment represents about 50 km × 50 km at 26 degrees latitude, all the above assessments were conducted rapidly, drawing from digital information and expert knowledge.

Anon. (2001) presented the status of weed distribution for each of the top 20 weeds of national significance on a small-scale map of Australia by assigning one of the following classes to each biogeographic region (Thackway and Cresswell 1995):

- abundant and widespread
- common and widespread
- occasional or localised
- absent
- no data.

All examples presented here have the desirable quality of describing absence as well as presence across the entire area of interest.

## Regional-scale mapping of mimosa status using existing data

Schultz (1987) represented mimosa populations at a regional level with a single point for each major infestation on a property. This method is suitable only for geographically discrete small infestations. Users of this database recognised this shortcoming and requested an improvement to better represent large infestations. An alternative method is described here.

A map of suitable habitat divided into areas of relatively homogeneous mimosa density and management strategy is ideal for presenting a regional overview of mimosa distribution. This regional mapping method involves the preparation of the map and the assignment of mimosa status to each discrete mapping unit from existing data and the knowledge of field officers. For the purposes of this paper this method will be called "regional mimosa status mapping". The method has not been tested but is presented here to promote it.

Preparation of the map and management of the associated information is easily conducted using a geographic information system (GIS). The map is basically the whole region split up into discrete areas by combining or overlaying two maps, suitable mimosa habitat and management boundaries. The resultant map has lines from both source maps.

After the preparation of the map, each discrete mapping unit or area is assigned a mimosa status. When the mapping units are coloured according to mimosa status, the distribution of mimosa over the region can be easily interpreted. The proposed task of assigning mimosa status is a two-stage process. The first step uses all existing data on mimosa distribution in the GIS to assign mimosa status. The next step distributes the map to field operators to improve the assessment of mimosa status with their expert knowledge. This is essential as the GIS data on mimosa distribution may be out-of-date or lacking in some areas.

The following are examples of the types of information that could be recorded for each of the mapping units. Suggested values are in brackets. More discussion is required on the maps and reports intended from these data before this list can be finalised:

- density class (unknown, absent, 1–10%, 11–50%, 51–100% projected foliage cover)
- area
- active control program (yes, no)
- date of last field inspection
- confidence that this assessment represents the situation at the date above (low, medium, high)
- management priority (low, medium, high).

The resultant mimosa status layer would be sufficient to plan and prioritise control and mapping action at the regional and catchment level. Maps could be created with any combination of these attributes to demonstrate the extent of the problem, argue for additional resources and demonstrate the benefits of coordinated control. Summary reports, such as the area of mimosa for each combination of catchment and density class, could be readily generated.

A sample map showing density and date of last field inspection was prepared (Figure 1). The map represents the digital data available to the authors. At this stage there are many areas where the density is unknown. This map would then be sent to field officers with a request that they fill in details according to guidelines. All mapping units that have been assigned a density other than "unknown" have a year printed on the mapping unit. The year represents the date of the field visit on which the assessment of density is based. This gives the interpreter of the map an appreciation of data quality. New versions of the map could be created periodically. Comparisons between the maps could be made using the GIS.

This method is the fastest way to gain an overview of mimosa distribution without having to conduct any expensive field mapping. The use of local knowledge could be considered as a weakness of this method, as assessments are subjective and therefore prone to error. However the fact that knowledge is combined with formal records could also be considered a strength, as the product enables decision-makers to access what is known to date before spending money on further mapping or control.

## Large-scale mapping by field observations, recording locations with a global positioning system (GPS)

Large-scale mapping by field observations is the most common method of mapping mimosa in the NT. Field officers search mimosa habitat on foot, quad bike, airboat or vehicle. Many different approaches have been used to record the location and to describe populations of mimosa at a location. These are summarised in Table 2.

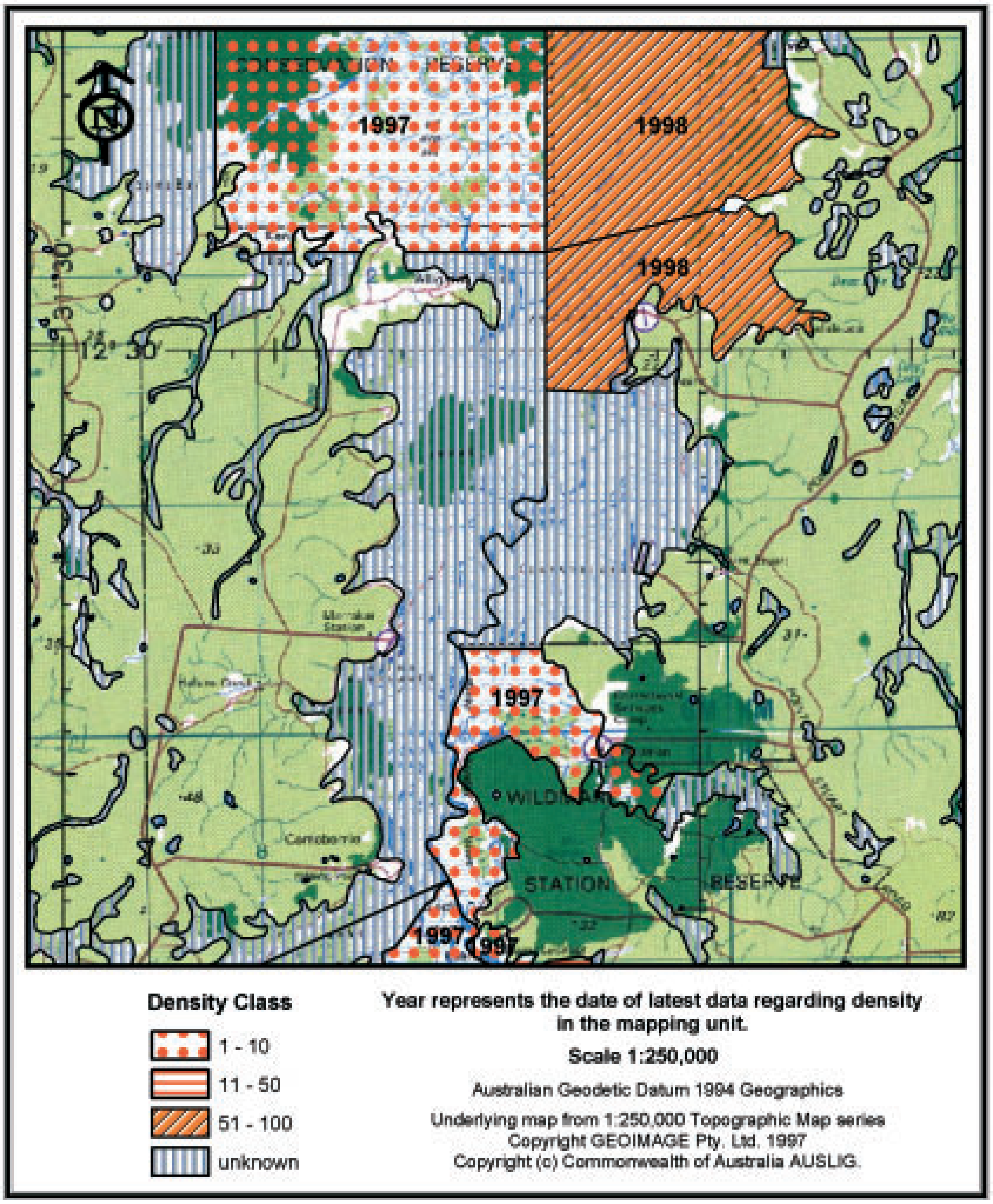


**Figure 1.** A sample mimosa status map.

The location is usually recorded as a single point, a line or a polygon. A polygon is an area enclosed in a line (like a circle or rectangle but with any shape). Each point, line or polygon is meant to represent an area of mimosa plants. A line is used in situations where the weed population is alongside a linear landscape feature like a road or watercourse. The location of the weed infestation is recorded with a line and the line thickened to the width to form an area in the GIS.

Single points are used to represent mimosa populations in three different ways, described in Table 2. Each has its own advantages. Area is good for calculating the total area of weeds but is subject to observer bias more than the other methods as there is no information on where the area of weeds estimated lies in relation to the point. A circle radius can also be used to calculate the infestation area and has the advantages of being able to be drawn on the GIS and gives officers reassessing the site a practical frame of reference for revisiting the area. The Kakadu National Park Mimosa Database recorded the numbers of plants in each growth stage and evidence of flowering. As demonstrated by Cook *et al.* (1996), this approach is appropriate for monitoring the treatment and recovery of areas with very few scattered plants, and where eradication is possible with consistent long-term management.

Two agencies that describe infestations by numbers of plants at a single point, have prescribed a limit to the population size that can be represented. Kakadu National Park assessment applies a 1 km radius limit, whereas the Montana Noxious Weeds Survey and Mapping System limits the number of plants represented by each point to a maximum of 50 (Cooksey and Shelley 1997).

In September 1999, the NT Weeds Branch defined a standard field format for the collection of data for Stage 1 of the NT Weeds Mapping and Management System. The standard field format is given at <http://www.nt.gov.au/dbird/dpif/plants/weeds/gis_techniques.shtml>. A form is also provided for recording single point data at <http://www.nt.gov.au/dbird/dpif/plants/weeds/pdf/form.pdf>.

Although mapping mimosa with GPS in the field results in a very comprehensive picture of weed distribution, it is time-consuming and therefore expensive. Also, it is difficult to map large populations with this method and to cover all suitable habitats, especially on floodplains with *Melaleuca* forest.

## Aerial survey

Aerial survey by helicopter has proven to be the best method for detecting small clumps and single mature mimosa plants, particularly in remote or inaccessible areas. Aerial surveying has the advantage of being unencumbered by the difficulties of terrain traversal. However, only mature plants can be detected by aerial survey. Seedlings and immature plants can be detected only in field surveys. Three distinct methods of aerial surveying have been used to date.

### *Method 1. Fixed flight path along parallel transects with observers (Transect)*

The first is a true systematic survey covering 100% of the potential habitat in the area of interest. This is done by flying along parallel transects with observers on both sides of the helicopter recording the percentage projected foliage cover of all weed species observed every six seconds. This method

**Table 2.** Methods for recording mimosa populations by GPS and their representation in the GIS.

| Location recorded in the field on the GPS | What it looks like in the GIS | Representation of population size in the GIS | Some systems that use this method |
|---|---|---|---|
| Single point | Point | Table column filled in by the mapper: | |
| | | area | WMMS[a] Stage 1 |
| | | or | |
| | | numbers of plants or | Kakadu National Park Mimosa Database (Cook *et al.* 1996) and the Montana Noxious Weeds Survey and Mapping System (Cooksey and Shelley 1997)<br>Likely addition to WMMS in Stage 2. |
| | | Circle radius | NT Parks and Wildlife Commission |
| Line (with width of weeds) | Polygon | Area in the associated table column, calculated by the GIS | WMMS Stage 1<br>Montana Noxious Weeds Survey and Mapping System |
| Polygon | Polygon | | |

[a] WMMS = Northern Territory Weed Mapping and Management System.

was used to map five weed species, including mimosa, over 500 km$^2$ of floodplains, covering reserves in the Mary River catchment, in 1997. Five days of surveying resulted in data suitable to produce 1:25,000 maps of the presence, absence and density of five weed species over the study area. Figure 2 shows results for mimosa over a small part of the study area.

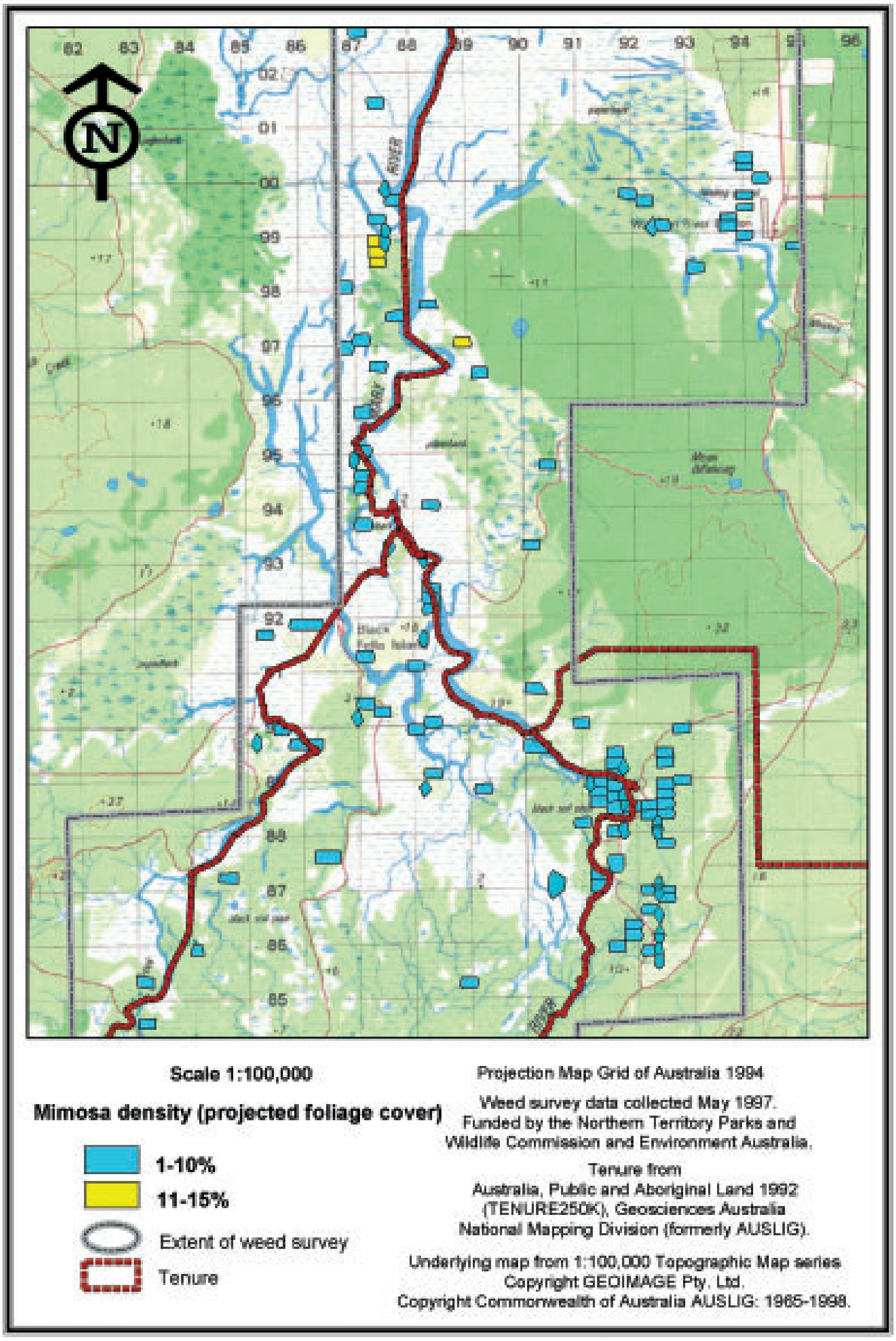


**Figure 2.** An example of the data produced from mapping with aerial survey method 1.

***Method 2. No fixed flight path with observers (Reconnaissance)***

This method entails the helicopter traversing watercourses and floodplains in no fixed format, with observers detecting mimosa patches. Locations of mimosa plants and clumps are recorded as points or polygons either by the GPS on the helicopter or hand-held GPS. This method has been used to search for new infestations over remote river systems in northern and eastern Arnhem Land.

***Method 3. Flight path outlining mimosa infestations with no observers other than the pilot (Outlining)***

This method relies on the helicopter pilot to detect and traverse the outline of all mimosa patches with the path of the helicopter. The outline is recorded on the GPS system in the helicopter. This method was used extensively by the NT Government during the 1990s to map infestations on the Moyle, Daly, Reynolds, Finniss, Adelaide and Mary River floodplains to provide an estimate of area covered by mimosa for calculating the cost of aerial spraying.

A brief comparison of the methods is given here. The Transect and Reconnaissance methods are more reliable; that is, if the same survey were conducted twice over the same area, the results would be very similar. This means that comparisons of surveys conducted with these methods over the years are more likely to show real changes in the population rather than a difference in how the pilot perceived the plant populations on the day, compared to the Outlining method. Maps produced from the Transect method show weed presence and absence; maps from the other methods only show weed presence. Density is recorded with the Transect method and can be recorded with the Reconnaissance method but not with the Outlining method. The movement of the helicopter during mapping with the Outlining method has made the most stalwart passengers airsick. The Transect method has the advantage of systematically covering all mimosa habitats, whereas the other methods rely on the pilot and the observers to keep track of all areas covered and to ensure that no areas have been missed. In practice this is very difficult to do. The cost of mapping with the Transect method is about three times the cost of the Outlining method, and the cost of the Reconnaissance method is less than that of the Outlining method.

## Aerial spraying

With the appropriate equipment, the path of the helicopter during spraying can be recorded on a GPS. These data can be converted in a GIS to a map of the area sprayed. They should be routinely collected for all aerial spraying operations to increase knowledge of mimosa distribution and its management.

## Aerial photography

Aerial photographs have been used successfully for strategic planning. Operators used the photographs as a surrogate map, taking advantage of the additional information on the photographs, such as terrain, roads and fences. In the NT, interpretation from photographs of the mimosa population was successful due to prior knowledge of the location and the extent of the infestations, and because the infestations were dense and extensive.

The author compared the utility of mapping scattered mimosa in the Mary River catchment in 1997 with the Transect method of aerial survey described earlier in this paper. Populations below 25% projected foliage cover over areas of 185 m × 280 m on the Mary River Floodplains in the south of Wildman Reserve, could not be detected on 1:15,000 aerial photographs (Sanford-Readhead, unpublished data). The photographs used in this assessment were possibly less than ideal for interpretation considering they were standard colour and taken a couple of months after the end of the active growing season. Pitt and Miller (1998) found the interpretation of mimosa easiest using infared rather than standard colour aerial photographs, and using photographs taken during the active growing season.

However, if considering aerial photography for mapping mimosa, note that it is difficult to obtain aerial photographs during the active growing season as this is the time of year when cloud-free days are few. Interpretation of the photographs is very time-consuming and the photographs are expensive. Also, converting photographs to a format that can be viewed on the GIS is a significant cost. Aerial photographs can provide useful information on the development of large and dense, known populations, over time. However, where the study area is large, the preparation of photographs is expensive, interpretation is time-consuming and they are not useful for detecting small mimosa infestations.

## Analysis of satellite imagery

Satellite-based mimosa mapping and monitoring has had mixed results over the past 15 years (Fitzpatrick 1989, Menges *et al.* 1996, Lyons 1999). The Landsat thematic mapper (TM) satellite sensor has been used to identify some large stands of mimosa, but has failed to accurately identify isolated patches. Automated classification of satellite imagery will not reliably differentiate mimosa when applied to different regions across the NT. This is because the satellite sensors detect the reflectance of sunlight from the Earth and variations in geomorphology, soil type, soil moisture (or surface water in many cases), stand density, and plant health across different environments. This creates too much variation in the response given by mimosa to separate it from other plants.

The satellite image is composed of pixels or cells that are 30 m square. Data on the reflectance of sunlight from the Earth in several parts of the electromagnetic spectrum (called "bands") are attached to each pixel. These data are combined and analysed in many ways to produce the maps we see from satellite imagery. Even with satellite imagery that has smaller pixel sizes and finer assessment of the reflectance of sunlight (spectral resolution) there is some concern about the prac-

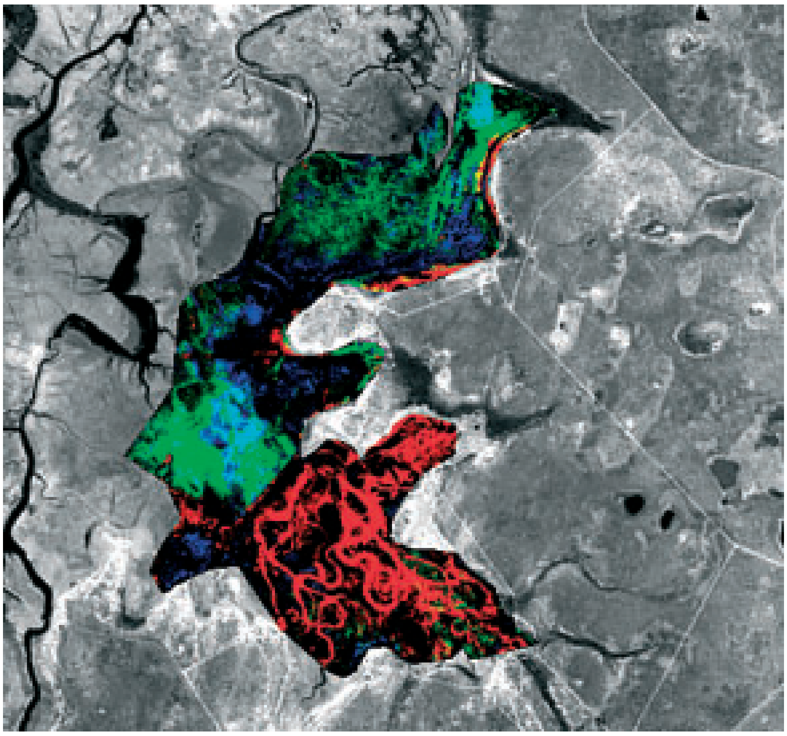

**Figure 3.** Area of mimosa showing condition trend based on 12 years of Landsat TM satellite data. Light green, dark green, and blue represent increases of mimosa, while red represents a decline.

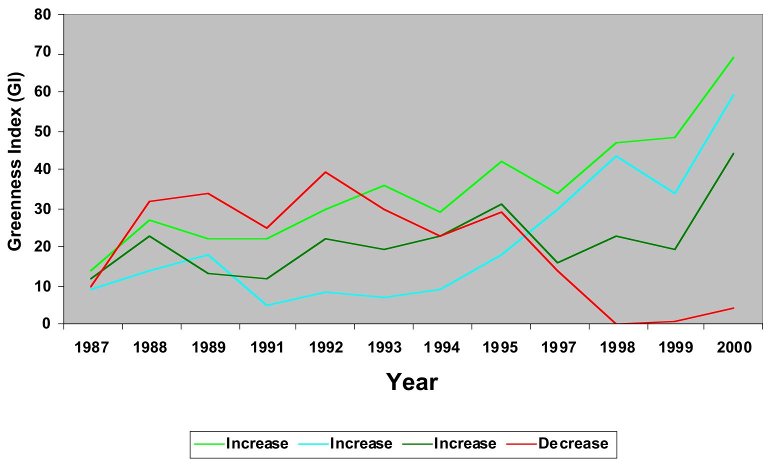


**Figure 4.** Graphical representation of changes of the greenness index over time. A clear decline of cover in the red areas can be linked to control efforts during the period 1997 to 1999.

tical limitations of delineating single species from this imagery (Okin *et al*. 2001). The key to using satellite imagery is to understand the practical limitations of the data and critical information requirements, and to tailor the analysis and expectations accordingly.

Broad-scale trends in landscape change can be monitored using temporal sets of satellite data. Temporal monitoring allows a retrospective approach using historical Landsat data integrated with current field data (Karfs *et al*. 2000). This technique develops an understanding of landscape process in response to changes in land use and associated impacts such as fire, changes in pastoral management and weed control (Hosking *et al*. 2001, Bach and Hosking 2002).

The approach used prior knowledge of the location, structure, health, and management of mimosa to interpret the cover and condition changes identified by the temporal assessment of satellite imagery. Substantial mimosa thickening and control activity was clearly identified from the trend data (Figure 3). In Figure 3, which shows an area in the Mary River catchment, red areas denote a substantial decrease in mimosa condition, whilst blue and green denote an overall increase in mimosa condition.

A measure of the condition of mimosa is the greenness index, obtained from the difference of two bands. This index has been found to correlate with plant condition (Hosking, unpublished data). Figure 4 depicts changes in greenness index from 1987 to 2000, for areas in Figure 3. The greenness index of each coloured area in Figure 4 is represented by the same colour used in Figure 3. The decrease in greenness index over the period 1997 to 1999 (red) corresponds with a decrease in mimosa condition due to extensive control efforts in this area.

The temporal assessment techniques used here are the product of a decade of work by a number of individuals, working together to develop the techniques and database of information to analyse and interpret Landsat imagery for this particular catchment. A suite of ground-based vegetation monitoring sites located across the catchment provided information essential to the interpretation of the imagery. As stated earlier, experience has shown that spectral response is unique due to all the interacting components in a particular environment. Significant effort is required to tailor the techniques developed to interpret mimosa trends for the Mary River Catchment to other catchments.

## Weed control plan maps

The preparation of these maps is described in this paper in a simple and general way. The NT Government encourages landholders to prepare weed control plans to facilitate effective allocation of resources on weed control (see <http://www.nt.gov.au/dbird/dpif/plants/weeds/weed_plan.shtml>). A weed control plan map should indicate the actions in a weed control plan.

The map is developed in stages. The first step is to obtain a property map, then divide the property into management zones, like paddocks, or special areas, such as watercourses. Next, mimosa distribution and density is broadly mapped by subdividing the management units into areas of homogeneous density using broad density classes, e.g. absent, scattered (covers less than 10% of the area), medium (11% to 50%) and dense (covers greater than 51% of the area). This requires a reasonable knowledge of the distribution and density of mimosa across the property. If this information is not available, then techniques described in this paper could be used to collect the information. The next step is to determine appropriate management strategy for each discrete area and give it a priority (see Figure 5). Advice on treatments and priorities can be obtained from NT Weed Management Officers <http://www.nt.gov.au/dbird/dpif/plants/weeds/weed_contacts.shtml>.

The weed control plan map will look like the sample map in Figure 5. The highest priority areas have the lowest density in accordance with the Mimosa Strategic Plan (Anon. 2001). The control strategy for the high priority areas in Figure 5 is to find and treat all plants with herbicide annually or preferably bi-annually. The mapping units with the lowest priority have dense, established, mimosa infestations. Strategies planned for these mapping units may include an integrated approach including biological control. Records should be kept for each discrete area.

The weed control plan map can be prepared using paper maps or a computer. The following resources can help. Hard-copy topographic maps, property maps and aerial photographs can be obtained from the NT Land Information Centre <http://www.lpe.nt.gov.au/info/mapping/default.htm>. If the mapping data available are out-of-date, it may be wise to obtain a rectified satellite image to use as a base map. Examine some potential products at <http://www.geoimage.com.au/>. Contact the NT Government to find out if it has any data on mimosa distribution over the area of interest. The person to contact for data is listed at <http://www.nt.gov.au/dbird/dpif/plants/weeds/gis_weeds.shtml>.

# Conclusion

All methods used to map mimosa in the NT over the past 10 years have been presented in this paper. The methods to use in any given situation

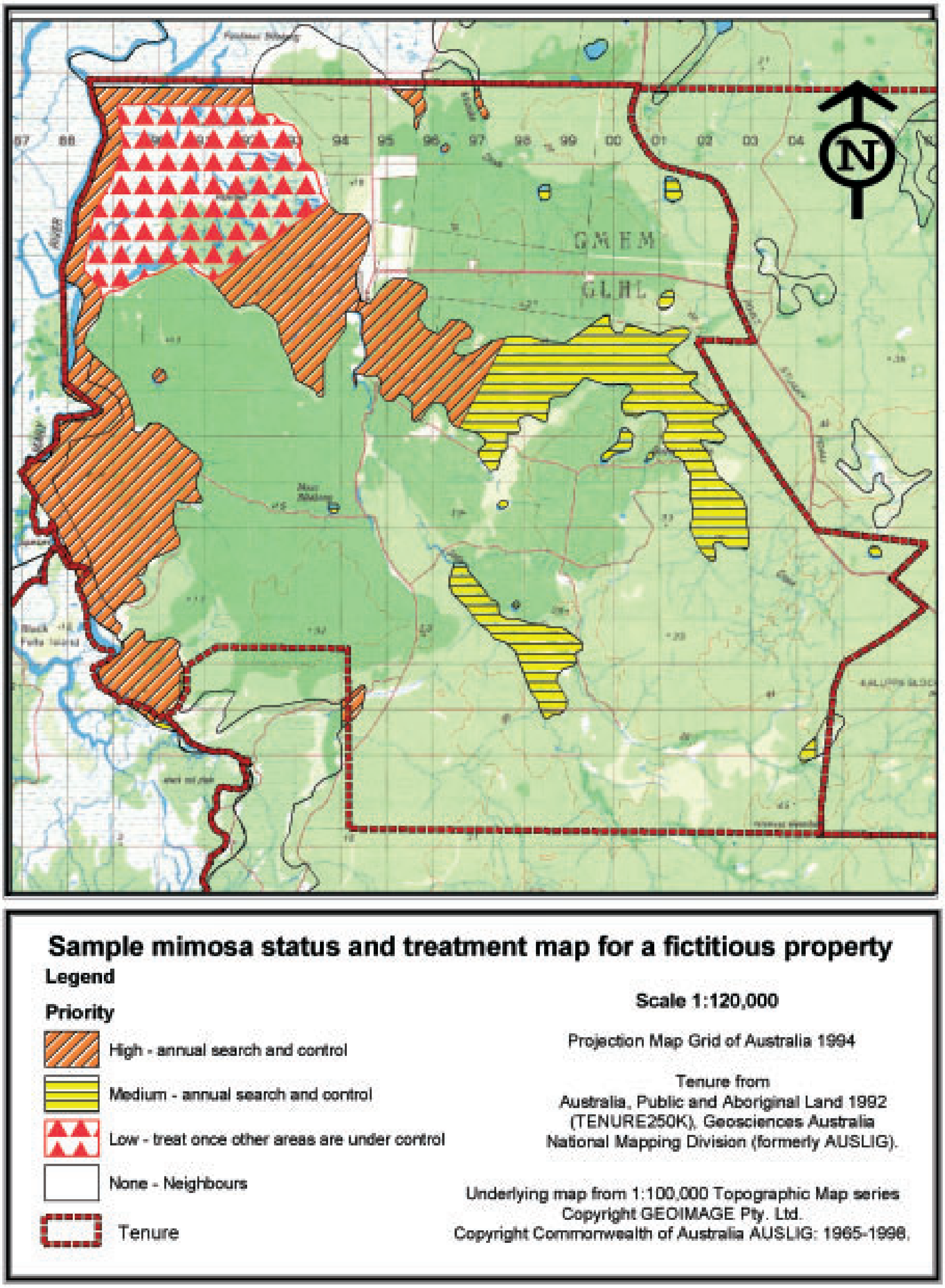


**Figure 5.** A weed control plan map prepared for demonstration purposes only.

will depend on the information needed for management, the appropriate map scale that will provide data in enough detail to answer the management questions, and the resources available for mapping. If comparison of mimosa density is required over time, the same method of mapping should be used in successive exercises. A limitation of analysing the results of existing data from different mapping techniques is the variation in the information available.

The Australian Mimosa Strategic Plan indicates that the identification and treatment of all small infestations of mimosa should be the highest priority (Anon. 2001). Therefore a high proportion of the mapping budget should go into detecting and recording small infestations of mimosa in regions where mimosa is absent or low in numbers. Mapping should use the Reconnaissance aerial survey method in remote regions, and field mapping with a GPS or the Transect aerial survey method in other areas. Information should then be disseminate to those who will be responsible for locating and treating the infestations.

The next priority for implementing the Australian Mimosa Strategic Plan (Anon. 2001) is to provide an overview of mimosa distribution and control status to assist the Committee responsible for implementing the plan. The GIS database produced by applying the regional mimosa status mapping method described in this paper would provide maps ideal for strategic planning.

Considering that mapping is expensive and there is a vast area of potential mimosa habitat in Australia, mapping should be conducted at the smallest scale that provides the information needed. There has been a preoccupation with recording mimosa in detail where mimosa populations are medium or dense, while missing the broader picture. The regional mimosa status mapping method and the weed control plan preparation method were developed to gather field knowledge and the limited available data to conduct strategic planning. The regional mimosa status mapping method should be tested. More research is necessary to develop mapping techniques that enable rapid recording of weed populations in the field, to make the process of mapping by aerial or field survey more efficient.

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