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## **A GIS Based Assessment of Land Suitable for Growing Hoop Pine in the Atherton, Eacham and Herberton Shires of North Queensland**

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### **ABSTRACT**

The area of private land suitable and available for growing hoop pine (*Araucaria cunninghamii*) on the Atherton Tablelands in North Queensland was modelled using a geographic information system (GIS). In Atherton, Eacham and Herberton shires, approximately 64,700 ha of privately owned land were identified as having a mean annual rainfall and soil type similar to Forestry Plantations Queensland (FPQ) hoop pine growth plots with an approximate growth rate of 20 m<sup>3</sup> per annum. Land with slope of over 25° and land covered with native vegetation were excluded in the estimation. If land which is currently used for high-value agriculture is also excluded, the net area of land potentially suitable and available for expansion of hoop pine plantations is approximately 22,900 ha. Expert silvicultural advice emphasized the role of site preparation and weed control in affecting the long-term growth rate of hoop pine. Hence, sites with less than optimal fertility and rainfall may be considered as being potentially suitable for growing hoop pine at a lower growth rate. The datasets had been prepared at various scales and differing precision for their description of land attributes. Therefore, the results of this investigation have limited applicability for planning at the individual farm level but are useful at the regional level to target areas for plantation expansion.

Keywords: spatial modelling, digital elevation model, Shuttle Radar Topography Mission

### **INTRODUCTION**

This paper describes the process whereby land suitable and potentially available for growing hoop pine in the Atherton, Eacham and Herberton shires in north Queensland (Figure 1) was identified using GIS-based modelling. The work was undertaken by the author as a member of a team from The University of Queensland

(UQ) investigating the prospects for hoop pine expansion on the southern Atherton Tablelands<sup>1</sup>.

Expanding the softwood plantation based timber industry on the Atherton Tablelands will be challenging because the area of FPQ<sup>2</sup> plantations in the region has never achieved the size necessary to attract a large-scale processing industry. In 2004-05, the FPQ plantation pine estate on the Atherton Tablelands was only 3604 ha and harvesting was limited to only 23,784 m<sup>3</sup> or 1% of the timber processed annually from plantations in Queensland (DPI Forestry 2006).

Modern large-scale processing plants require a timber resource that is far in excess of what FPQ plantations in the Atherton Tablelands can supply. For example, the Hyne and Son plantation pine processing plant in south-east Queensland was upgraded in 2002 so that it can process up to 600,000 m<sup>3</sup> of plantation softwood per annum (DPI&F, 2004a). The shortfall of timber resource cannot be supplied from private plantations. In 2002-03, private plantation forestry in Queensland only supplied 189,000 of the 2.1 M m<sup>3</sup> of plantation-grown wood processed (DPI&F 2004b).

Fortunately, Commonwealth government support for plantation forestry is strong, with the Hon. Eric Abetz, Minister for Fisheries, Forestry and Conservation supporting plantation forestry because of its importance for the development of downstream processing industries (Halkett 2006). The Department of Transport and Regional Services' (DOTARS) commissioning of 'a business case, implementation plan and supporting data analysis and regional models in relation to the Hoop Pine processing industries on the Atherton Tablelands' (DOTARS 2006), reinforces this support.

In order to undertake the investigation the UQ team needed information concerning:

- the area of land in the region which is biophysically suitable for growing hoop pine, i.e. 'suitable' land and
- the area of privately owned land which is suitable for growing hoop pine and is also potentially available because there are no restrictions on its use for plantations. This category of 'available' land excludes land which is covered

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<sup>1</sup> A Deed of Agreement for the Hoop Pine Plantation Project was signed between DOTARS (under their national Sustainable Regions Program) and the Herberton Shire Council for the development of a business case and implementation plan undertaken by a research team coordinated by the UQ School of Natural and Rural Systems Management.

<sup>2</sup> From May 2006, the group within the Queensland Department of Primary industries and Fisheries, Forestry (DPI Forestry) managing the Queensland Government's 190,000 hectare softwood and 10,000 hectare hardwood forest plantation estate was separated off as a stand-alone business unit known as Forestry Plantations Queensland.

with native vegetation, buildings and infrastructure, or is used for high-value agriculture.

Relevant information was available in various datasets of land tenure, rainfall, soil type, elevation, residual native vegetation and agricultural land use. This suggested the use of a GIS to present the data in a format suitable for socio-economic modelling.

The capability of modern GIS software to model spatial datasets has improved dramatically in recent years and the increased memory of personal computers has permitted the modelling of spatial datasets at the regional level. However, the uncertainties inherent in extrapolating patterns in biophysical parameters over landscapes suggested that in this case modelling undertaken to classify land according to its suitability for hoop pine should be linked to the growth of hoop pine on field reference sites. Fortunately, FPQ data were available from growth plots in local plantations and these growth plots became the major reference point for the GIS analysis.

Following sections of this paper describe the modelling process whereby GIS-compatible datasets were analysed to produce estimates of suitable<sup>3</sup> and available land in each shire. The estimates were then referenced against the performance of FPQ growth plots to produce an estimate of the area of land which would grow hoop pine at a similar growth rate to local FPQ plantations.

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<sup>3</sup> In this report the word 'suitable' is synonymous with other authors' use of 'capable' in relation to the capacity of land to grow trees.

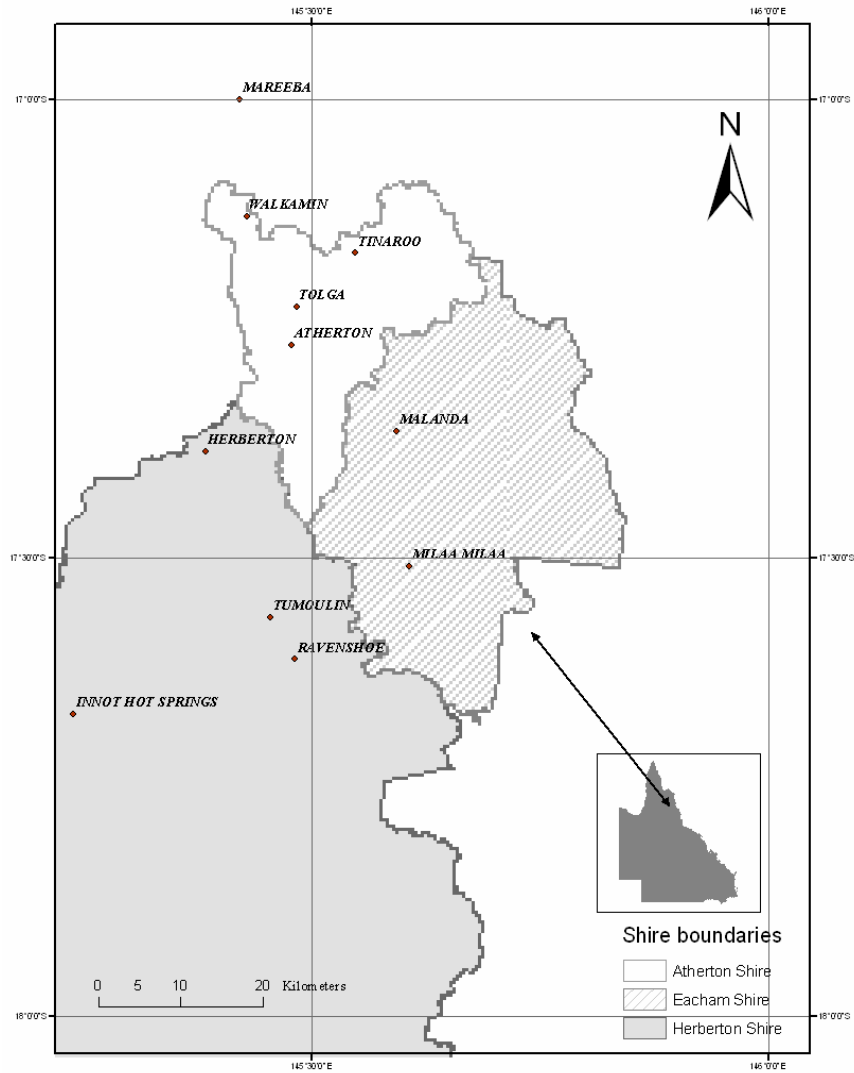


Figure 1. Location of the study area comprising Atherton, Eacham and the northern part of Herberton shires

## PREVIOUS LAND CAPABILITY ASSESSMENTS AND EXTENSION LITERATURE

Two recent investigations had been undertaken to provide an estimate of the scope for plantation expansion in the Far North Queensland statistical division. Annandale *et al.* (2003) reported on the suitability and availability of land within 200 km of Cairns for small-scale forestry, particularly eucalypts. Astuti (2004) submitted a thesis describing potential sites for growing hoop pine on the Atherton Tablelands as part of a Master of Natural Resource Studies with UQ. Neither report could be used as a guide to the area of land in the shires which is both suitable and available for growing hoop pine. Annandale *et al.* (2003) did not incorporate soil type as a factor of suitability. They also chose the city of Cairns as the node from which zones of suitability were referenced, which may not be useful for log haulage to sawmills on the Atherton tablelands. The report overestimated suitable land because it classified rainfall into mean annual rainfall suitability zones with the lowest zone being 600 - 800 mm. This rainfall zone is marginal for hoop pine plantations.

Astuti (2004) used expert opinion to delineate the soil and rainfall parameters applicable to four suitability types. Although there is sufficient empirical data from FPQ growth plots to support the classification of land into an 'optimal' site suitability class, data are lacking for other situations. Expert opinion provided for this investigation emphasized the effect of early-age<sup>4</sup> silviculture on the long-term growth rate of plantations (Keady 2006; Ryan 2006). Consequently, soil characteristics alone may not be a reliable guide to hoop pine growth and Astuti's estimates for the lower suitability classes cannot be validated.

The literature which might be expected to be used by farmers as a guide to growing and managing hoop pine includes three publications titled *Hoop Pine for Wood Production* (DNR 1996), *Weed Management for Successful Plant Establishment* (NRMW 2001) and *Hardwood Plantations in Queensland – Good Establishment Practice* (DPI 2002). These are available as printed brochures or as a compact disc titled *Planted Forestry Information Kit* which is produced by the Department of Natural and Resources, Mines and Water (NRMW)<sup>5</sup>. While the advice is general in nature, all three government extension publications stress the need for early-age weed control and the advantages of cultivation during site preparation to improve tree growth. The first publication suggests a minimum annual rainfall of 800 mm and well-drained alluvial or volcanic soil for growing hoop pine. All three publications also suggest an optimal regime of cultivation, fertilization and weed control and imply that any less intense management will result in poorer growth. It logically follows that with the less-than-perfect management regime applied by many small-scale foresters, there

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<sup>4</sup> Early-age silviculture includes site preparation, weed control and fertilizing.

<sup>5</sup> This department has been renamed as the Department of Natural Resources and Water (NRW).

is an inherent danger in recommending marginal soils or rainfall zones for hoop pine. Alternatively, it may be possible to grow hoop pine at a lower growth rate on some slightly less fertile soils, as long as early-age silviculture is kept at an optimum level. This suggests that only fertile soil – i.e. soil types in Astuti's 'high' and 'medium' suitability class – should be considered as land suitable for growing hoop pine.

In summary, Astuti's study and the extension literature suggested that provided that early age silviculture is optimal, the fertile basaltic soils of the Atherton Tablelands are capable of growing hoop pine at similar rates to FPQ plantations, i.e. an approximate mean annual increment (MAI) of 20 m<sup>3</sup>/ha/year. It also suggested that the soil types which Astuti labelled as 'medium' suitability may be capable of growing hoop pine at an undefined lower rate provided early-age silviculture is optimal.

### MODELLING PROCEDURE

The modelling was done using the ArcGIS<sup>®</sup> software suite produced by the Environmental Systems Research Institute (ESRI) because of its ability to accommodate various file formats in common use. Because electronic files were obtained from various sources, they were configured as both vector (polygon, line and point) and raster (cell) format. Consequently, the general modelling process involved converting the polygons to raster format and using the capability of the Spatial Analyst<sup>™</sup> and 3D Analyst<sup>™</sup> extensions to undertake cell-based modelling. The software enabled land areas which are unavailable for growing hoop pine for various reasons to be excluded from land areas which are biophysically suitable for growing hoop pine, providing a net estimate of the area of land which is both suitable and available.

The survey area included all of Atherton and Eacham shires and the northern part of Herberton shire, extending approximately 10 km south of the town of Ravenshoe. The modelling process was undertaken with datasets which describe the topography, topology<sup>6</sup> and attributes of the land in the three shires. The datasets were:

1. The digital cadastral database (DCDB) for each shire, showing the area, location and shape of each land parcel within the shire, provided by NRMW as polygon shapefiles<sup>7</sup>.
2. A database of all land (estates) owned by the Queensland Government, principally State Forest and National Parks, provided by NRMW as polygon shapefiles.

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<sup>6</sup> In GIS, topology is the model which describes the geometric relationship of features to each other.

<sup>7</sup> A *shapefile* is a vector data storage format for storing the locations, shapes and attributes of geographic features.

3. Version 5.0 of the Regional Ecosystem<sup>8</sup> (RE) boundaries for each shire, provided by the Environmental Protection Agency (EPA 2005) through the Queensland Herbarium, as polygon shapefiles. The RE maps show land which is covered in native vegetation and which for this investigation was not considered to be available for conversion to hoop pine plantation.
4. Soils maps of the region compiled by Malcolm *et al.* (1999), provided by NRMW as polygon shapefiles.
5. A digital elevation model (DEM) for each shire, obtained by downloading data from the Shuttle Radar Topography Mission (SRTM) web site (<http://srtm.usgs.gov>) as 3 arc-second raster data.
6. Long-term mean annual rainfall data for the region, provided by the Australian Bureau of Meteorology as 9 arc-second raster data.
7. A map of agricultural landuse, provided by the Queensland Land Use Mapping Program (QLUMP) as polygon shapefiles. The map shows Australian Land Use and Management (ALUM) land classifications.

#### **Attribute and Positional Accuracy and Usefulness of the Datasets**

The datasets had differing levels of precision for both location and qualitative attributes. Locations in the DCDB and estates files were only defined by surveyed boundaries in Atherton Shire. SRTM elevation data with a pixel size of approximately 90 m was checked against spot heights marked for the tops of mountains on 1:50,000 Australian topographic survey maps of the region and found to be approximately within 10 m of the spot heights. This is in accord with the random error of less than 10 vertical metres quoted in STRM product release notes for north Queensland (SRTM 2006). The horizontal position of these points was checked and found to be within several hundred metres of their position on the map.

Other datasets were mapped to varying criteria of accuracy. For example, the RE maps were drawn with minimum remnant polygon areas of 5 ha (EPA 2004) and the sampling intensity of the soil maps was a minimum of one ground observation site per 100 ha for grazing land (Malcolm *et al.* 1999). In both cases, small areas of vegetation or soil type may not have been mapped.

Because ALUM land-use classifications are intended to provide land-use information for users across Australia (BRS 2004), they encompass a wide range of rural pursuits. BRS (2002) claimed an accuracy of the assignment of polygons to the correct land-use class of 80% of cases, so problems with the usefulness of the dataset are mainly confined to the general nature of the definitions of land use.

The boundaries of the long-term mean annual rainfall classes were determined by reclassifying rainfall data with continuous variation over the landscape, into discrete

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<sup>8</sup> Regional ecosystems are vegetation communities that are consistently associated with a particular combination of geology, landform and soil.

rainfall classes. A different reclassification would have resulted in different rainfall suitability zones and consequently different estimates of the areas which were suitable for growing hoop pine.

### Steps in the Modelling Process

The modelling process was carried out in eight steps:

1. A file of the boundary of each shire was created so that it could be used as a mask file with which to clip other datasets to the boundaries of Atherton, Eacham and Herberton Shires respectively.
2. The estates and the RE files were clipped using the mask files to create separate files of the estates and residual native vegetation in each shire.
3. The estates and RE files were amalgamated for each shire to create polygon files representing the total area of land which is unavailable in each shire.
4. A DEM which covered the area of each shire was downloaded from the SRTM web site. Using Spatial Analyst<sup>TM</sup>, the 3 arc-second cells of the DEM were converted into a model of the slope of the terrain and reclassified into two categories of land, viz. land less than 25° in slope and steeper land. This file was then overlaid onto the amalgamated estates-RE file.
5. The raster dataset of mean annual long-term rainfall was reclassified according to Astuti's productivity classes. The mean annual rainfall classes were: less than 750 mm (unsuitable); between 750 and 1000 mm (low suitability); between 1000 and 1300 mm (medium suitability); and greater than 1300 mm (high suitability) (Figure 2).
6. Files of the soil survey undertaken by Malcolm *et al.* (1999) which cover Atherton Shire, most of Eacham Shire and the northern part of Herberton Shire were used to classify soil into suitability classes. Soil types classified by Astuti as being highly suitable and of medium suitability were identified and made into separate files for each shire. These files were converted into raster format.
7. Spatial Analyst<sup>TM</sup> was used to remove the amalgamated RE and estates polygons i.e. land which is designated as RE or estates from the raster files of each soil suitability class (Figure 3). The net area of suitable and available land for each soil suitability class was collated for each shire and rainfall class (Table 1).
8. The area of suitable and available land calculated in step 7 was further reduced by subtracting the area which was classified by QLUMP as water features or being used for intensive agriculture and irrigation (Table 2 and Figure 4).



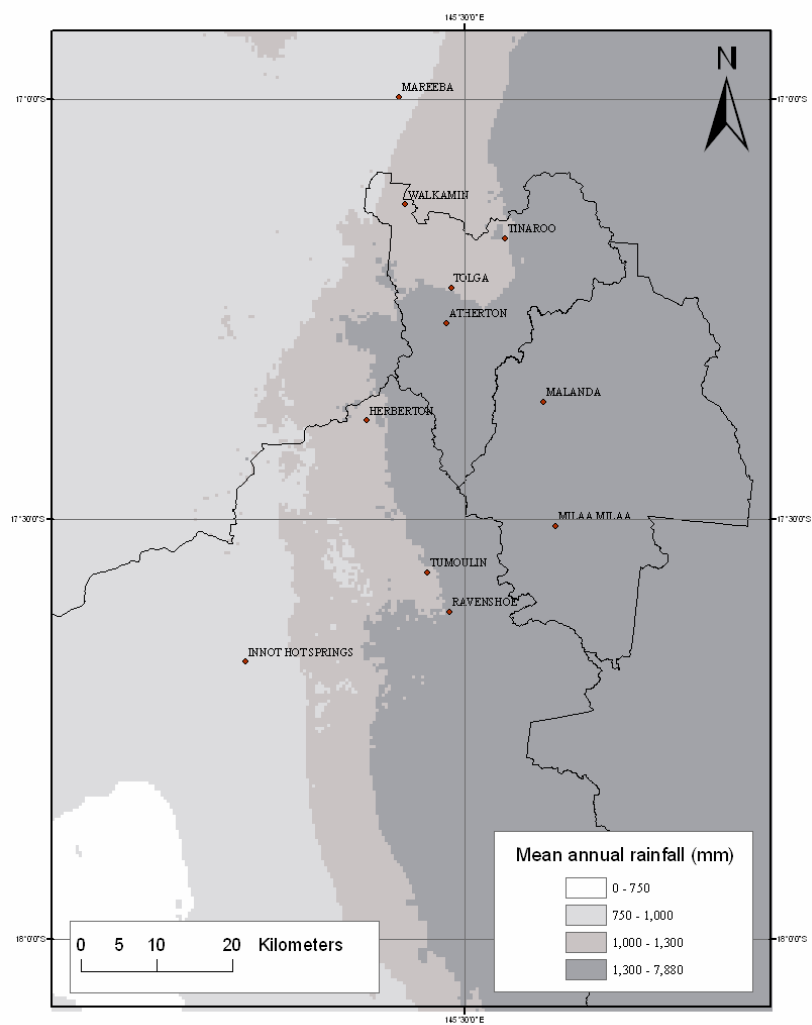


Figure 2. Mean annual long-term rainfall classes for the Atherton Tablelands

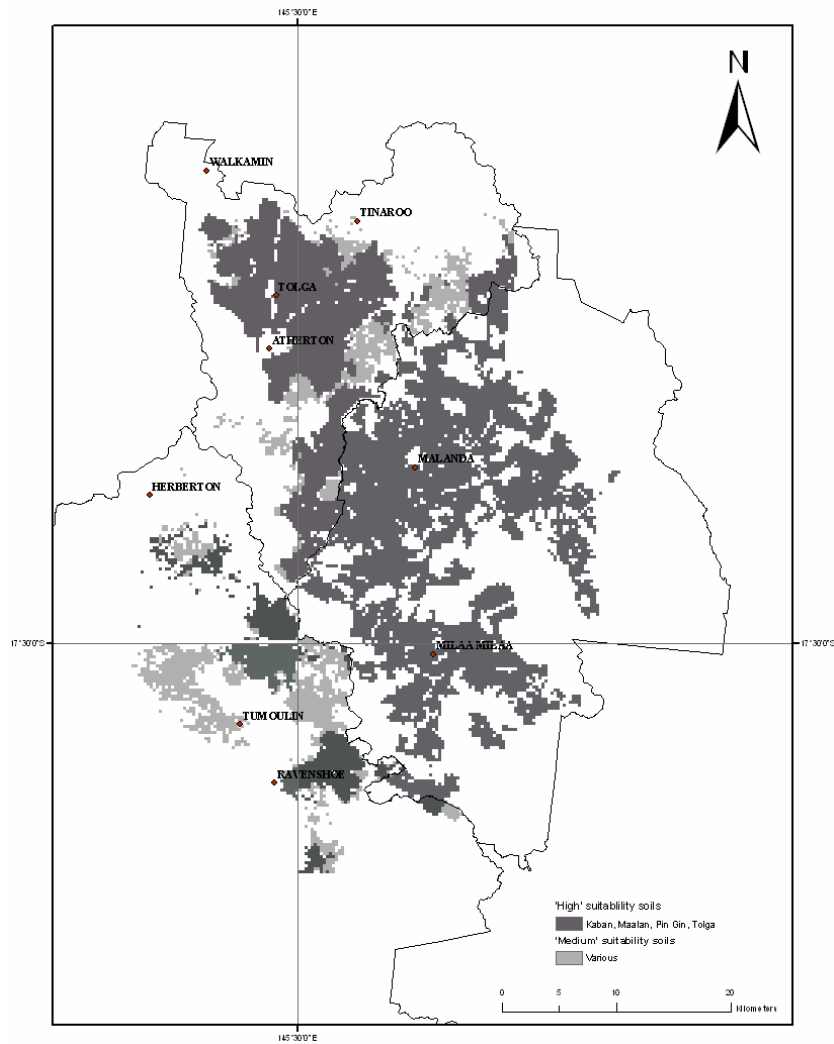


Figure 3. Areas with soils of 'high' and 'medium' fertility on privately owned land which is potentially available for growing hoop pine

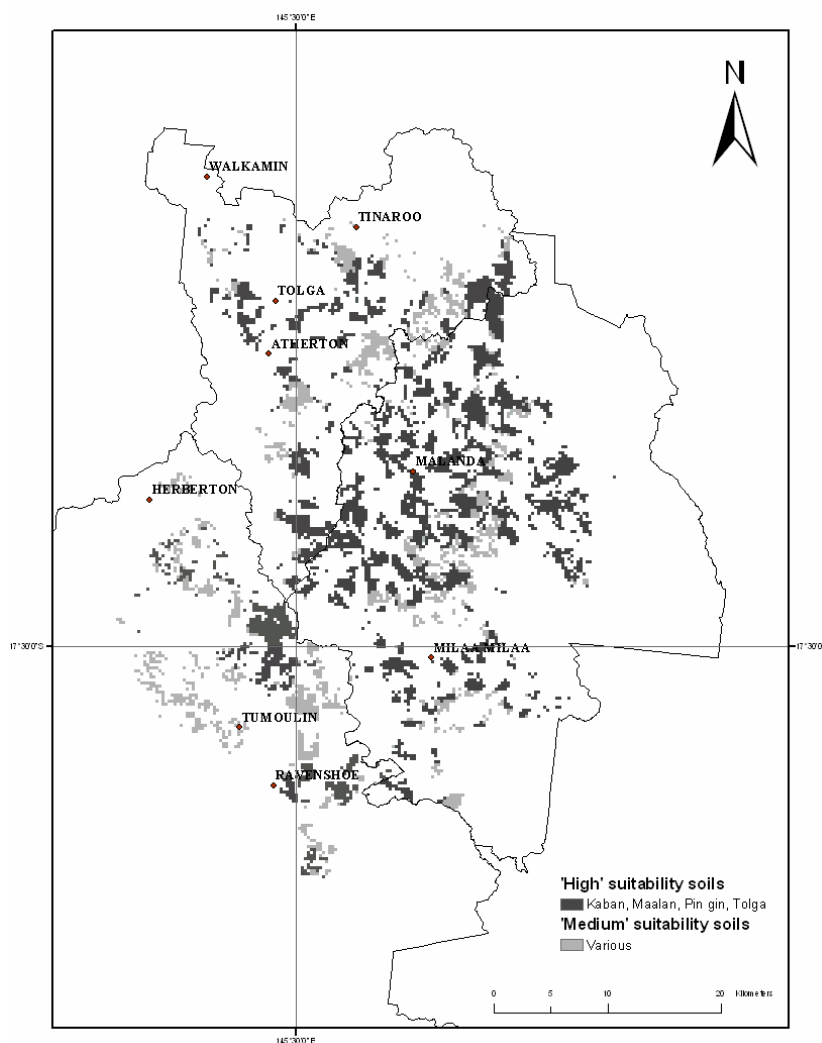


Figure 4. Net area of land on the southern Atherton Tablelands which is both suitable and available for growing hoop pine

### CALCULATION OF THE AREA OF SUITABLE AND AVAILABLE LAND

The estimated areas<sup>9</sup> of available land with soil types having a high suitability for growing hoop pine in Atherton, Eacham and Herberton Shires are 19,700, 37,900 and 7100 ha respectively (Table 1). The area of available land with soil types having a medium suitability for growing hoop pine in Atherton, Eacham and Herberton Shires is estimated as 5400, 8800 and 7400 ha, respectively (Table 1).

Table 1. Area of land in Atherton, Eacham and Herberton Shires suitable and available for growing hoop pine, for annual rainfall zones of 1000 –1300 mm and >1300 mm

Land classification	Atherton Shire <sup>10</sup>			Eacham Shire			Herberton Shire		
	Area (ha)	Area (ha) classified by rainfall zone		Area (ha)	Area (ha) classified by rainfall zone		Area (ha)	Area (ha) classified by rainfall zone	
		>1300	1000 - 1300		>1300	1000 - 1300		>1300	1000 - 1300
High suitability soils	21,100			51,700			11,600		
Less estates and RE	1400			13,800			4500		
Net area	19,700	12,300	7400	37,900	37,900		7100	6800	300
Medium suitability soils	13,600			23,200			17,400		
Less estates and RE	8200			14,400			10,000		
Net area	5400	4700	700	8800	8100	700	7400	4500	2900

The further subtraction of land which is used for intensive agriculture or irrigation left only 22,900 ha of land available and of high suitability for hoop pine plantations,

<sup>9</sup> When polygons are converted to cells during cell-based GIS modelling, unless the centre of the cells which cover a polygon actually cover the polygon surface, that portion of the polygon is classified as 'no data'. The proportion of polygon area classified as 'no data' increases with larger cell sizes and more convoluted polygon boundaries. For the modelling undertaken here, cell size was kept at 0.000833 decimal degrees (88.68 m) because original raster datasets were supplied at this cell size. When highly irregularly shaped polygon features were converted to raster format, approximately 3% of the land area was classified as 'no data' cells and removed from calculations. Hence all area estimates have been rounded to the nearest 100 ha.

<sup>10</sup> The gross area of Atherton Shire is approximately 63,200 ha, the gross area of Eacham Shire is approximately 112,700 ha and the gross area of Herberton Shire is approximately 950,400 ha.

i.e. 5100, 14,300 and 3500 ha in the Atherton, Eacham and Herberton shires respectively (Table 2). For medium suitability soils, the area of available land is 3000, 3600 and 4000 ha for the respective shires (Table 2).

Table 2. Area of land in Atherton, Eacham and Herberton Shires suitable and available for growing hoop pine, less areas used for intensive agriculture, for annual rainfall zones of 1000–1300 mm and greater than 1300 mm

Land Classification	Atherton Shire			Eacham Shire		Herberton Shire	
	Area (ha)	Area (ha) classified by rainfall zone		Area (ha)	Area (ha) classified by rainfall zone	Area (ha)	Area (ha) classified by rainfall zone
		>1300	1000 - 1300		>1300		1000 - 1300
High suitability soils	19,700			37,900		7100	
Less land used for intensive agriculture	14,600			23,600		3600	
Net area	5100	4000	1100	14,300	14,300	3500	3300 200
Medium suitability soils	5400			8800		7400	
Less land used for intensive agriculture	1400			5200		3400	
Net area	3000	2500		3600	3600	4000	2500 1500

Mean annual rainfall is only an approximate surrogate for the adequacy of the supply of water to plants. However, in the absence of alternative data relating to water availability, the classification of rainfall classes used here would appear to be appropriate. All of Eacham Shire and most of Atherton and Herberton shires have a mean annual rainfall classified as optimal (> 1300 mm) for hoop pine growth (Table 3). Rainfall is therefore not an inhibiting factor for the growth of hoop pine over much of the Atherton Tablelands.

Steep land (> 25° in slope) was invariably found on areas which are covered in natural vegetation or are part of Queensland State or local government estates. Hence steep land in these locations was automatically excluded from calculations of available land. However, small areas of very steep land are common over these landscapes and the operation of rubber-tyred tractors or skidders on this land would not be acceptable under current Workplace Health and Safety legislation. It was not possible to exclude these small steep areas.

Table 3. Area of land in Atherton, Eacham and Herberton shires by annual rainfall class.

Rainfall (mm)	Atherton Shire area (ha)	Eacham Shire area (ha)	Herberton Shire area (ha)
< 750 mm			89,700
750–1000 mm	800		540,300
1000–1300 mm	15,200		136,700
>1300 mm	42,700	112,700	183,700

## DISCUSSION AND CONCLUSION

For this investigation, the effect of combining datasets of suitable or available land and only selecting land (pixels) which satisfy all criteria, was to calculate the minimum land area potentially available on the southern Atherton Tablelands for plantation expansion. For very small areas, however, the delineation of suitable and available land was not possible. Anecdotal evidence suggests that farmers have strong preconceptions about which part of their farms they may be willing to allocate to plantations in moderate to high rainfall areas near the Queensland coast. Expert opinion provided for this investigation indicated that to some extent the lower fertility of ‘medium’ soil types could be compensated by intensive site preparation and early-age silviculture.

Some small farms in the region are also being managed for lifestyle pursuits. Establishment costs may not be a problem for these owners and the low maintenance requirements of plantations in later years may also be attractive. Alternatively, owners of larger farms with a focus on agricultural production may prefer to grow tree species which are less demanding of soil fertility, particularly eucalypts.

The handbook for the Spatial Analyst™ software warns that care should be taken in calculating and interpreting indices derived from qualitative and quantitative attributes (ESRI 2001). For example, in this investigation a *continuous* distribution of long-term mean annual rainfall over the landscape was reclassified into a *categorical* distribution of four broad rainfall classes. Reclassification according to different criteria may have resulted in an entirely different set of statistics. A similar situation could occur if the soils had been classified differently into suitability classes. Also, reclassification into broad categorical suitability classes resulted in a loss of intra-class variation, that is, trends within the classes were lost.

For the purposes of regional planning, the implications of these results are that between 22,900 and 64,700 ha of land is suitable and potentially available for growing hoop pine within the three shires. In northern Australia, economic problems for tropical agriculture are likely to lead to fertile land which is close to ports becoming available for timber plantations (Underwood 2006). While there are many other factors to be considered, if plantation forestry is to be encouraged on the Atherton

Tablelands, this GIS-based model has shown that a considerable area of land is available which could be expected to grow hoop pine at a similar rate to FPQ plantations.

### ACKNOWLEDGMENTS

The assistance of Paul Ryan and Eric Keady in providing advice as to the uncertainties associated with modelling biophysical parameters was most appreciated. In particular, their comments that early-age silviculture can drastically affect the growth of plantations serves as a caution to the interpretation of GIS-based growth and yield estimates.

### REFERENCES

- ANNANDALE, M., BRISTOW, M., STOREY, R. and WILLIAMS, K. 2003. *Land Suitability for Plantation Establishment within 200 Kilometres of Cairns*. Queensland Department of Primary Industries, AFFS/QFRI, Brisbane.
- ASTUTI, I.E. 2004. *A Land Capability Study to Identify the Potential Sites on the Atherton Tablelands for Hoop Pine Plantation Establishment using Geographical Information Systems and Expert Opinion*. Thesis submitted as partial fulfilment of a Master of Natural Resource Studies. The University of Queensland, Gatton, Australia.
- BRS (BUREAU OF RURAL SCIENCES). 2002. *Land Use Mapping at Catchment Scale: Procedures and Definitions*. [http://www.affa.gov.au/corporate\\_docs/publications/pdf/rural\\_science/landuse/definitions\\_ed2.pdf](http://www.affa.gov.au/corporate_docs/publications/pdf/rural_science/landuse/definitions_ed2.pdf) Accessed 26 June 2006.
- BRS (BUREAU OF RURAL SCIENCES). 2004. *Australian Land Use and Management Classification (ALUM)* <http://www.daff.gov.au/content/output.cfm?ObjectID=3EE8599D-2C6A-4DF3-83ACB3820C5BEDC0> Accessed 26 June 2006.
- DNR (DEPARTMENT OF NATURAL RESOURCES). 1996. Hoop Pine for Wood Production. *Planted Forestry information Kit: A Collation of Information for Farm Foresters*, Compact Disc, Department of Natural Resources and Mines, Brisbane.
- DOTARS (DEPARTMENT OF TRANSPORT AND REGIONAL SERVICES). 2006. Approved Projects. <http://www.sustainableregions.gov.au/qld/ath/projects.aspx> Accessed 22 August 2006.
- DPI (DEPARTMENT OF PRIMARY INDUSTRIES). 2002. *Hardwood Plantations in Queensland – Good Establishment Practice*. *Planted Forestry Information Kit: A Collation of Information for Farm Foresters*. Compact Disc, Department of Natural Resources and Mines, Brisbane.
- DPI FORESTRY (DEPARTMENT OF PRIMARY INDUSTRIES, FORESTRY). 2006. *DPI Forestry Pocket Facts, 2006*. <http://www2.dpi.qld.gov.au/dpiforestry/14687.html> Accessed 21 August 2006.

- DPI&F (DEPARTMENT OF PRIMARY INDUSTRIES AND FISHERIES). 2004a. *Hyne and Son – Timber Product Manufacturer, Wholesaler and Retailer*. <http://www2.dpi.qld.gov.au/forestrybook/16572.html> Accessed 21 August 2006.
- DPI&F (DEPARTMENT OF PRIMARY INDUSTRIES AND FISHERIES) 2004b. *The Processing Sector*. <http://www2.dpi.qld.gov.au/forestrybook/16564.html> Accessed 21 August 2006.
- EPA (ENVIRONMENTAL PROTECTION AGENCY). 2004. Survey and Mapping. [http://www.epa.qld.gov.au/nature\\_conservation/plants/queensland\\_herbarium/survey\\_and\\_mapping/](http://www.epa.qld.gov.au/nature_conservation/plants/queensland_herbarium/survey_and_mapping/) Accessed 24 June 2006.
- EPA (ENVIRONMENTAL PROTECTION AGENCY). 2005. *Pre-Clearing and 2003 Remnant Vegetation Communities and Regional Ecosystems of Queensland*. Compact Disc, Queensland Herbarium, Brisbane.
- ESRI (ENVIRONMENTAL SYSTEMS RESEARCH INSTITUTE). 2001. *Using ArcGIS Spatial Analyst*. Redlands, California.
- HALKETT, J. 2006. Batting for forestry. *Inwood*. **69**: 16–17.
- KEADY, E. 2006. Manager, Marketing Resources, Forestry Plantations Queensland. Personal Communication. 22 February 2006.
- MALCOLM, D.T., NAGEL, B.K. A., SINCLAIR, I. and HEINER, I.J. 1999. *Soils and Agricultural Land Suitability of the Atherton Tablelands North Queensland*. Department of Natural Resources. Brisbane.
- NRMW (NATURAL RESOURCES MINES and WATER). 2001. *Weed Management for Successful Plant Establishment. Planted Forestry information Kit: A Collation of Information for Farm Forester*. Compact Disc, Department of Natural Resources and Mines, Brisbane.
- RYAN, P. 2006. Principal Scientist, Horticulture and Forestry Science Forest Technologies, Department of Primary Industries and Fisheries, Queensland. Personal Communication. 20 February 2006.
- SRTM (SHUTTLE RADAR TOPOGRAPHY MISSION). 2006. <http://www2.jpl.nasa.gov/srtm/> Accessed 24 June 2006.
- UNDERWOOD, R. 2006. Prospects for high-value hardwood timber plantations in the dry tropics of Northern Australia. *Australian Forestry*. **69**(2): 142–154.