



ENHANCING KEY ELEMENTS OF THE VALUE CHAIN FOR PLANTATION GROWN WOOD IN LAO PDR

Mapping and Characterisation of Plantation Teak in Luang Prabang Province, Lao PDR

Objective 1, Activity 1.1 : Final Report

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VALTIP2

Disclaimer

This report was prepared as a research output from Project FST/2010/012, “*Enhancing Key Elements of the Value Chains for Plantation-Grown Wood in Lao PDR*” funded by the Australian Centre for International Agricultural Research (ACIAR), with the aim of *improving livelihoods for farmers and processing workers and the international competitiveness of Lao PDR wood industries through improved efficiency of the planted wood value chain*. The contents and views represent the views of the authors and do not necessarily represent the views of the Government of Lao PDR, the Australian Government, or of ACIAR.

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1 Introduction

This study is part of a project funded by the Australian Centre for International Agricultural Research (ACIAR) on “Enhancing Key Elements of the Value Chains for Plantation-Grown Wood in Lao PDR” (Project FST/2012/012, VALTIP2), which has an overall aim to improve livelihoods for farmers and processing workers, and the international competitiveness of Lao PDR wood industries through improved efficiency of key elements of the planted wood value chain. Specific objectives of the project were to:

1. address constraints and inefficiencies in the timber value chain, from harvest to processor stages, that limit returns to smallholder growers;
2. increase returns to processors and smallholders through improved efficiencies of the primary wood processing sector;
3. improve the value and quality of wood products for domestic and export markets; and
4. enhance the competitiveness and capacity of wood processing industries.

This paper contributes to part of Objective 1, by addressing the research question “What is the extent and age class distribution of smallholder planted trees available for value added processing in the Luang Prabang region?”

2 Background

The lack of precise information about the extent and nature of the plantation resource in Lao PDR is viewed as a constraint in the timber value chain. Improved knowledge of the extent of plantations is needed to enhance industry decision making and investment in value-added processing.

Plantations in Lao PDR include Eucalyptus, Acacia, Rubber, Teak and other indigenous species. While the main tree plantation species by area in Lao PDR is Rubber (*Hevea Brasiliensis*), most rubber plantations do not have wood production as their primary use. Most Eucalyptus and Acacia plantations have been established through projects involving foreign investors in partnership with the government, as joint ventures, or with local land owners (refer Smith 2016) and resource information is held by those investors. Teak (*Tectona grandis*) is grown in small plantations established by farmers and it is this component of the plantation resource that this project addresses, with a focus on Luang Prabang Province.

Teak plantations in Luang Prabang Province have expanded considerably over the last 25 years. Government promotion and incentives associated with land reforms and the Land and Forest Allocation policy of the early 1990's enabled the establishment of privately owned plantations across the country. However, current information on the extent of these plantations is based only on broad estimates made on the basis of District records, with little or no data on their location or structure. Reported areas of smallholder teak in Luang Prabang Province vary considerably from 10,000 ha in 2007 (Midgely *et al.* 2007), 20,000 ha in 2014 (Dieters *et al.* 2014) to 26 000 ha (Midgely *et al.* 2016). Total areas of Teak plantation in Laos also vary, with estimates between 40,000 ha (Midgely *et al.* 2016) and 50,000 ha (DOF 2015). None of these estimations are based on direct information of the extent of teak plantations.

Knowing the extent and characteristics of teak plantation is important for industry development, and value adding to the local economy is unlikely to occur without accurate information on resource availability.

This project addresses these issues by mapping the teak plantations across the province to provide:

- A more precise estimate of the total area of the teak plantations.
- Geographical structure of the plantation areas in terms of location and patch size.
- Estimates of stand structure to provide initial quantification of the resource and the basis for future ground inventory and volume estimation.

The project also aims to build capacity within Lao PDR; this project included the provision to Lao project participants of:

- Training and experience in forest mapping through the use of remote sensing imagery in a Geographical Information System (GIS) environment.
- Acquisition of recent remote sensing imagery across the province.
- Techniques for acquisition of mapping data.
- Capacity to undertake further mapping and analyses for a variety of purposes.

3 Methodology

The ACIAR project was designed on the basis of the use of satellite imagery for forest mapping and made a number of assumptions about the availability and utility of satellite imagery. The primary assumption was that SPOT satellite imagery that had been acquired by Department of Forestry (DoF) would be available and suitable for the purposes of the project. Further investigation found that this was not the case. The imagery was not freely available and was too old (2005).

The suitability and availability of other remote sensing imagery was subsequently reviewed. The essential requirement of suitable imagery was that it be of a resolution that enabled consistent identification and quantification of teak crowns and canopy to provide for accurate boundary definition and delineation of stand age or size. Experience in both remote sensing research and forest management has shown that image pixel resolution needs to be < 2m to be able to do this. Resolution below 1m is much more desirable giving more accurate outputs with less effort in both the mapping and the subsequent inventory. A summary of the imagery reviewed is provided in **Table 1**. Costs are in AUD as at 2013.

Table 1: Imagery Suitability

Imagery	Resolution	Coverage	Date	Cost/License	Suitability
ALOS AVINR 2	10m	Full	2009-10	Nil, free distribute	Unsuitable resolution
RAPIDEYE	6.5m	Full	2010-11	Nil, 1 license - DoF	Unsuitable resolution
SPOT5	2.5m	Full	2005	Nil, DoF?	Too old, marginal resolution
SPOT5	2.5m	Full	2013	\$35-50,000	Marginal resolution
FORMOSAT	2m	Full	2013	\$100,000	Marginal resolution
IKONOS	1m	Full	2013	\$300,000+	Suitable
QUICKBIRD	0.6m	Full	2013	\$300,000+	Suitable
GEOEYE	0.4m	Full	2013	\$400,000	Suitable
Lao NGD	0.3m	Full	2013	\$13,000	Suitable

The most suitable and cost effective option was found to be 3-band colour digital aerial imagery, with a resolution of 0.5m pixel size, captured 2013-2014 by National Geographic Department (NGD) of Lao PDR.

Imagery for the southern two-thirds of Luang Prabang Province was acquired by the project in May 2014. Subsequent delays in data capture and processing experienced by NGD saw the acquisition of the imagery for the northern 1/3 of the province in March 2016.

3.1 Methodology

Project Output 1 was the development of methods for mapping.

The mapping had two aims:

- Identification and delineation of teak plantations
- Delineation and estimation of plantation size class

ESRI ARCGIS 10.1 software was used for the mapping. The individual images were mosaicked together in map-sheet blocks for ease of use in the GIS. Multivariate image classification methods were tested with the imagery but were found to be unsuitable due to:

- Variable colour balance
- Variable appearance of the teak plantations. Presence/absence of leaves, understorey conditions, small size of plantations, tree density and tree size were the main contributors to the variation.

Manual interpretation combined with field checking was found to be the most accurate in identifying teak and also enabled estimation of size classes. Manual interpretation combined flexible pattern recognition with knowledge of landscape and land use to improve identification of teak. Consistency was provided by regular field checking and cross checking between mappers. Field checking efficiency was gained by the use of a GPS enabled digital camera; ground photos could be uploaded and viewed in the GIS for direct reference to the mapping.

Mapping commenced in June 2014. A sample area was mapped to determine an appropriate and achievable mapping classification. The minimum polygon size was initially set at 0.5 ha as an achievable resolution for the project timeframe and budget. After the training and initial mapping it was determined that a smaller minimum polygon size was achievable within the project constraints. This was set at 0.35ha.

A subset area was also mapped down to a polygon size of 0.16ha (1 *rai*) to provide for estimation of smaller areas of plantation of 0.16 – 0.35 ha.

3.1.1 Mapping Classification

Reliably mapping the age class, which is typically done on the basis of tree size and crown size/features, was found to be difficult due to significant variation between plantations in their tree size at the same age. Size class was determined a more reliable and appropriate measure of the structure of plantations, and more relevant to industry, and as result this was used as the classification for the mapping.

Mapping classes were subsequently designed to:

- Cover the range of plantation size and structure
- Be consistently identified and mapped
- Provide for stratification for future volume inventory

Dominant size class describes situations in which more than 50% of the basal area (BA) of the plantation has a diameter at breast height (dbh) range as specified. For classes 4, 5 and 6 this is not specified.

For partially stocked areas classes 1T, 2T, 3T describe stands where stocking is 60%-90% of a fully stocked plantation. For class 1T this is usually a result of partial planting failure or competition with other growth. In classes 2T and 3T this is more likely to be a result of partial harvests.

Table 2: Mapping Classification

Class	Dominant Size Class (dbh)	Class Description
1	< 15cm	Small, fully stocked
1T	< 15cm	Small, partially stocked
2	15-25cm	Intermediate, fully stocked
2T	15-25cm	Intermediate, partially stocked
3	> 25cm	Large, fully stocked
3T	> 25cm	Large, partially stocked
4	all	Mixed size
5	all	Partial plantation
6	all	Possible plantation

Class 4 describes areas where no dominant size class occurs and a mix of 2 or more size classes are found. This can be a result of adjacent small areas being planted at different times but more commonly by multiple partial harvests with subdominants and coppice growth occupying the gaps. This class can have variable stocking down to 60% of a fully stocked stand.

For partially stocked areas with 30%-60% of a fully stocked stand class 5 is used.

Class 6 is for areas where some of the identity indicators for teak plantation are observable but not enough for clear identification.

Areas of <30% are not classed as plantation.

Photo 1: Class 1

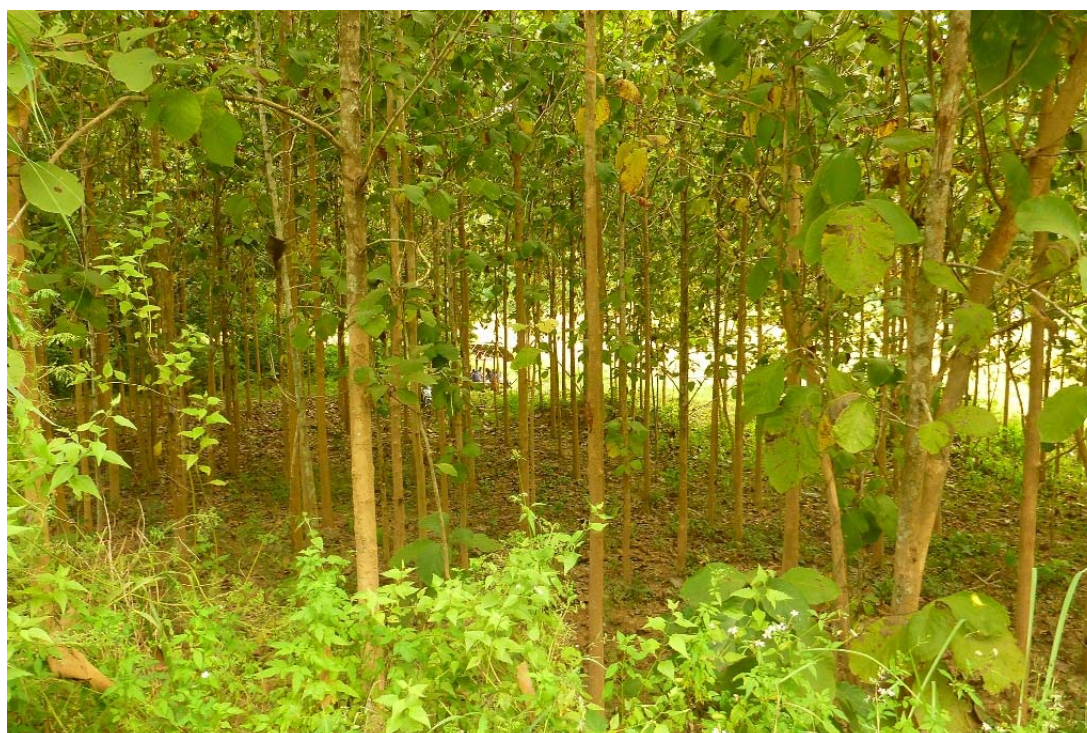


Photo 2: Class 2



Photo 3: Class 3

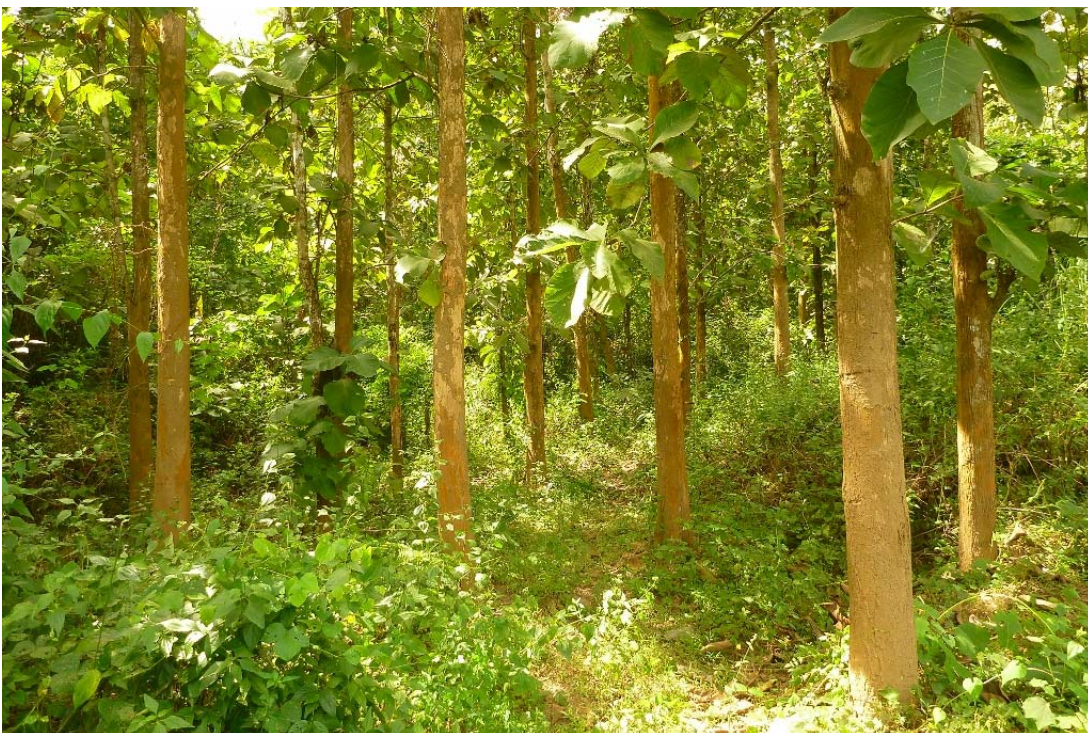


Photo 4: Class 4



3.1.2 Mapping Challenges

The colour balance of the imagery was found to vary across the images, a common characteristic of aerial imagery which is a result of the range of capture dates and times.

The landscape and environment of Laos presented some challenges to vegetation mapping using remote sensing imagery. The subtropical climate means that significant parts of the year have cloud cover levels that prohibit imagery capture. Dry season (November to February) is the optimal time to avoid cloud but also has a greater sun angle which is less optimal for minimising shadow.

Shadow is also exacerbated by the geography of Laos. As in many parts of Laos, Luang Prabang province has a rugged landscape. Most of the north, north east, east and southeast of the province is mountainous and sparsely populated whilst in the more populous areas limestone karst mountains occur in close proximity to agricultural zones. These features make it difficult to avoid shadow areas in imagery capture.

Areas on the imagery affected by shadow and cloud were calculated: 7 % of the total area of the province is affected by cloud or shadow on the imagery. It is important to note, however, that most of these shadow affected areas occur in rugged country where there is also a low probability of teak plantations occurring.

For some areas affected by shadow Google Earth imagery of sufficient clarity and suitable capture date was used to infill the mapping of teak plantations.

Teak is deciduous and is most easily identified from imagery when it has dropped its leaves. This occurs in the dry season, November – March, which coincided with the imagery capture period. Most but not all teak had dropped its leaves at time of image capture. However, dry season variation and early or late imagery capture for some areas meant that some teak was fully or partially leaved at time of capture. This was most prevalent for the northern block of imagery.

Conversely, the characterisation of the size class of teak is easier when the teak is leaved, with the fuller crown signatures making size estimation easier. Consistent interpretation needed to take into account these variations and pattern recognition by mappers was adjusted accordingly.

4 Results and Analysis

Project Outputs 2 and 3 were to delineate, map and communicate extent of Luang Prabang teak resource, and map and communicate the age class distribution of resource.

The mapping of the extent and structure class of the teak occurred simultaneously.

On the acquisition of the first block of imagery, the mapping program was able to proceed. Luang Prabang Teak Program (LPTP) provided the office, computer, GIS software and other equipment required. An officer from the Provisional Forest Service was engaged to undertake the mapping. Training in mapping was undertaken in June 2014. Mapping of plantations was completed in July 2016. GIS analyses were conducted in August 2016.

4.1 Area of Teak

The total area of teak plantation mapped in Luang Prabang Province, with polygons larger than 0.35 ha in size, was **15,342** ha (Map 1). In summary:

- A total of 11,699 polygons were mapped.
- The median polygon size was 0.92 ha. Median polygon size is driven largely splitting teak plantations into size classes.
- Median plantation/patch size was 0.98 ha. A plantation unit or patch is informative of the geographical size of contiguous plantation areas.
- The maximum plantation unit size was 157.5 ha,
- The total number of plantation units was 7418.

To estimate the area of small teak plantations 0.16 – 0.35 ha in size, the smaller areas were mapped over a 100,000 mapsheet area E_48_1, which included the city of Luang Prabang and surrounding areas (Map 3). The ratio of small area plantation to larger plantation in the sample area was used to calculate the area over the province. The results of this mapping were:

- Area of teak plantations 0.16 – 0.35 ha within E_48_1 mapsheet was 134 ha
- Area of teak plantations > 0.35 ha within E_48_1 mapsheet was 7175 ha
- Estimated area of teak plantations 0.16 – 0.35 ha in LPB province was 287 ha

4.2 Size Class

The plantations were found to be predominantly of small tree size; 39% of the area was dominated by trees < 15cm dbh (diameter at breast height) in classes 1 and 1T; and more than 75% < 25cm dbh (classes 1, 1T, 2, 2T and part 4, 5, 6). Only around 4 % was found to be > 25cm dbh (Classes 3 and 3T) (Table 3 and Figure 1).

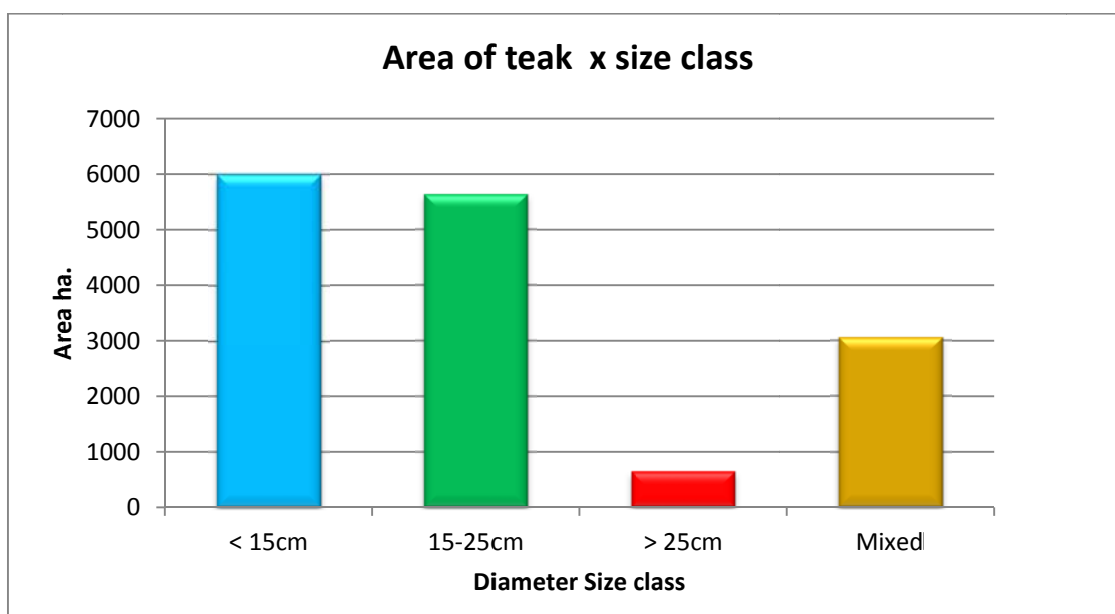
The partial stocking found in classes 2T, 3T, 5 and the mixed size class 4, comprising 28% of the plantation area, are likely to be a result of partial harvesting. Partial harvesting is commonly the removal of the largest, most saleable trees. The older the plantation the more likely it has experienced multiple partial harvests.

It is not possible at this stage to quantify with any level of certainty the proportion of the resource that would be of merchantable size. Only classes 3 and 3T would be predominantly merchantable. Classes 2, 2T, 4, 5 and 6 will contain some trees and areas of merchantable trees. Quantification of this requires field inventory and volume calculation.

Table 3: Area of Teak by Mapped Size Class

Teak Class	DBH Size Class	Description	Area (ha)	Area %
1	< 15cm	Young, fully stocked	4881	32%
1T	< 15cm	Young, partially stocked	1123	7%
2	15-25cm	Intermediate, fully stocked	4377	29%
2T	15-25cm	Intermediate, partially stocked	1255	8%
3	> 25cm	Large, fully stocked	372	2%
3T	> 25cm	Large, partially stocked	275	2%
4	Mixed	Mixed size	1555	10%
5	Mixed	Partial plantation	1184	8%
6	Mixed	Possible plantation	320	2%
Total			15342	100%

Figure 1: Area of Teak by Size Class



4.3 Auditing of Mapping

Auditing of the mapping was undertaken in the southern part of the province in November 2015. A sample of 166 polygons was selected, being representative of the mapping across the area, and were checked in the field for accuracy of size classification. The results showed that accuracy was high, with 80% of the polygons checked being correctly classified.

Due to delays in imagery acquisition, subsequent auditing of mapping in the northern part of the province did not occur.

4.3.1 Geographical distribution of teak plantations

Some preliminary analysis of the geographic distribution of teak polygons has been undertaken.

As can be seen in Map 1 the teak is clustered around the city of Luang Prabang and Table 4 shows the clustering in terms of area within defined radii from Luang Prabang.

More than half of the teak (57%) was found to be less than 25 km in a direct line from Luang Prabang and 75% is less than 50km.

Table 4: Proximity of Teak to Luang Prabang

Distance (km) from Luang Prabang	Area (ha) within Distance	Area % within Distance
5	843	5%
10	2,726	18%
25	8,716	57%
50	11,467	75%
100	14,712	96%
All	15,342	100%

The area of teak in each district in Luang Prabang province was also calculated (Table 5) and is shown in Map 4. The area of teak decreases in districts further from Luang Prabang – an indication of, amongst other factors, the flow of information and extension services for teak establishment and management and access to markets.

Table 5: Teak in Luang Prabang Districts

District	Size Class < 15cm	15-25cm	> 25cm	Mixed	Total
Luang Prabang	1,763	178	1,582	927	4,451
Pak Ou	1,070	31	965	310	2,377
Xiang Ngeun	819	128	762	486	2,194
Chomphet	626	61	525	444	1,656
Ngoy	458	93	477	215	1,243
Nan	514	36	471	201	1,223
Nambak	404	43	355	248	1,050
Pakxeng	116	50	213	96	475
Viangkham	131	19	191	99	441
Phonxai	101	7	90	31	228
Phoukhoun	0	0	2	1	3

The distribution of teak clearly follows the road network (Map 5) and proximity to roads is also a measure of accessibility and indicative of harvest and haulage cost.

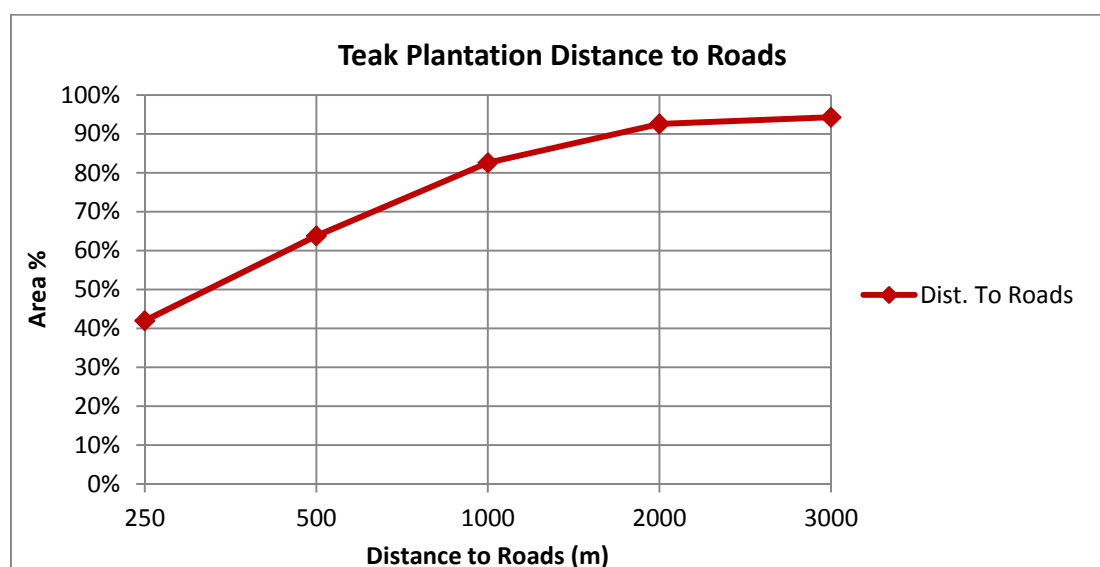
Roads included in the analysis were sealed roads and long life unsealed roads suitable for use by trucks. Not included were minor roads and tracks suitable for use by smaller vehicles although these may also be used for the transport of logs. The existing road mapping was incomplete so review and remapping of the roads layer in the GIS was required.

The analysis showed that 83% of the mapped plantation area was less than 1km from a road, and the accessibility of most plantations is good.

Table 6: Teak Proximity to Roads

Distance (m)	Area (ha) within Distance	Area % within Distance
250	6,437	42%
500	9,782	64%
1000	12,668	83%
2000	14,198	93%
3000	14,462	94%
All	15,342	100%

Figure 2: Teak Proximity to Roads



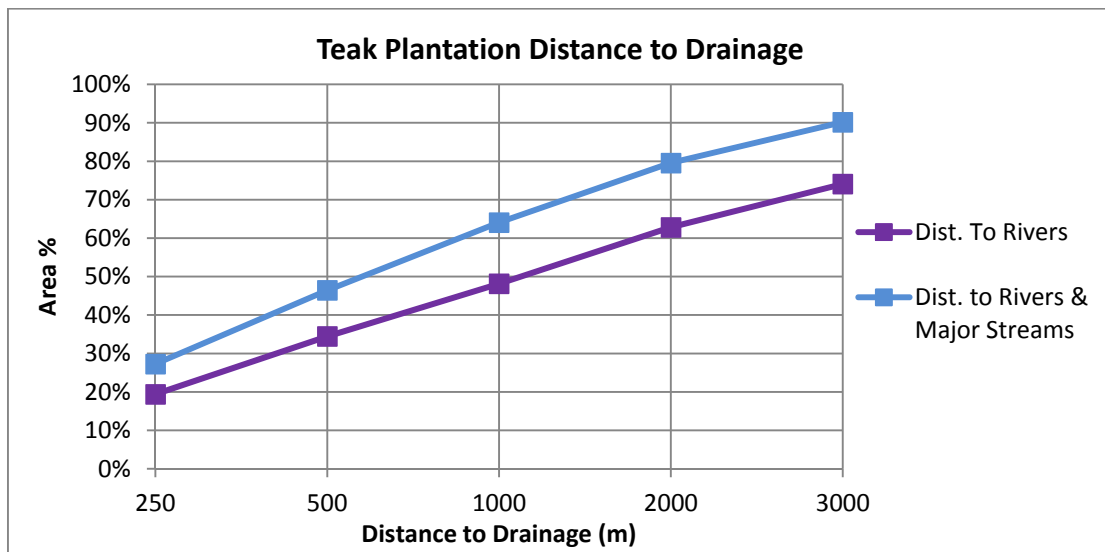
Proximity of Teak plantations to rivers and major streams¹ was also included in assessment because these have provided a means of past access for plantation establishment and the transportation of logs after harvesting. Proximity of teak to these features is also indicative of the occupancy of arable land, most of which is close to rivers and major streams. The establishment of plantations on agricultural land was discouraged in plantation promotion policies and land competition for agricultural crops is viewed as an issue in resource sustainability; plantations in arable areas may be at high risk of not being replanted in the future. Further analysis would be required to accurately quantify the impact of the plantations in the agricultural landscape.

Table 7: Teak Proximity to Drainage

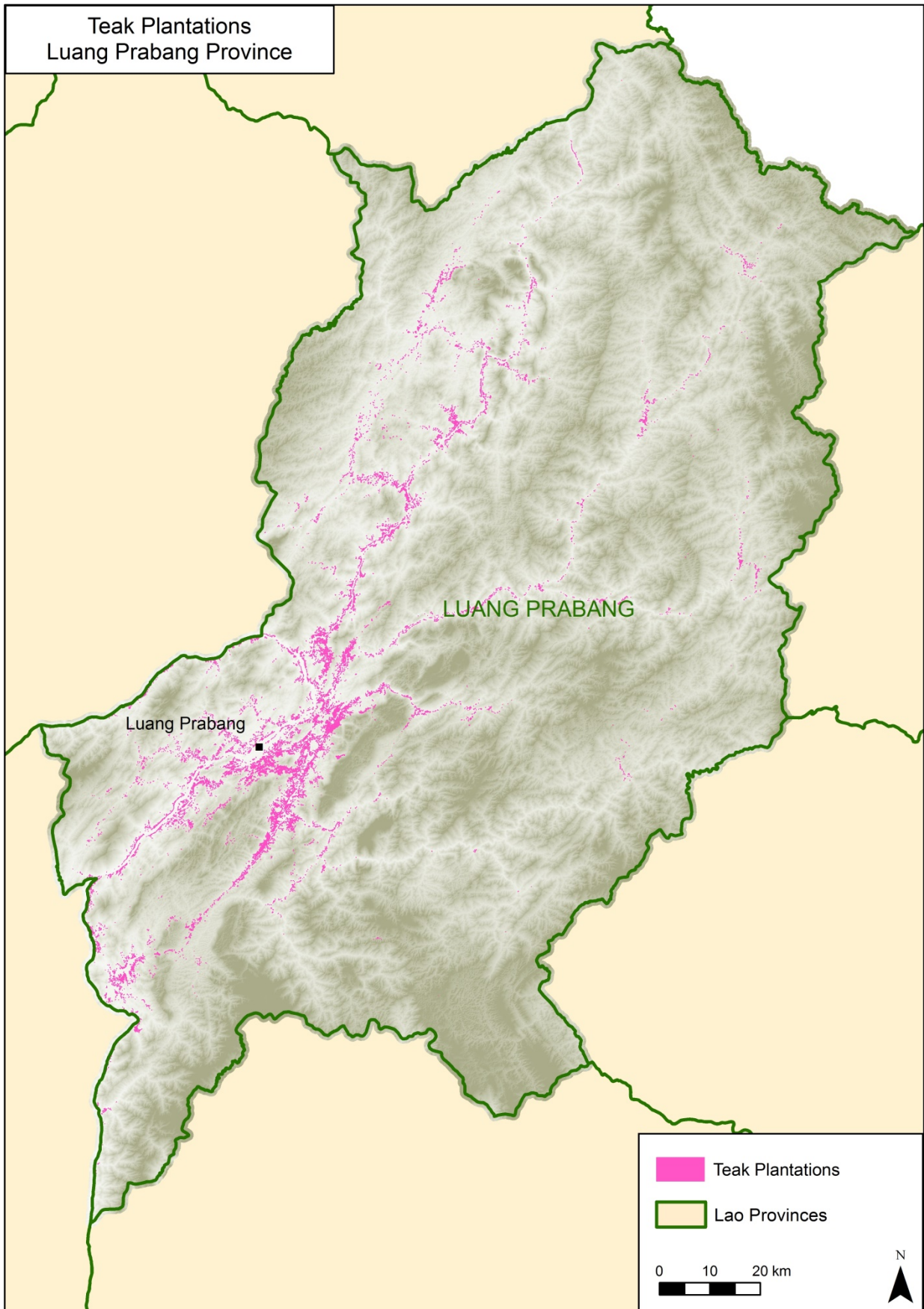
Distance (m)	Rivers		Rivers and Major Streams	
	Area (ha) within Dist.	Area % within Dist.	Area (ha) within Dist.	Area % within Dist.
250	2,976	19%	4,183	27%
500	5,284	34%	7,126	46%
1000	7,388	48%	9,828	64%
2000	9,638	63%	12,205	80%
3000	11,365	74%	13,833	90%
All	15,342	100%	15,342	100%

¹ Major streams are permanent water courses with a catchment size > 5000 ha.

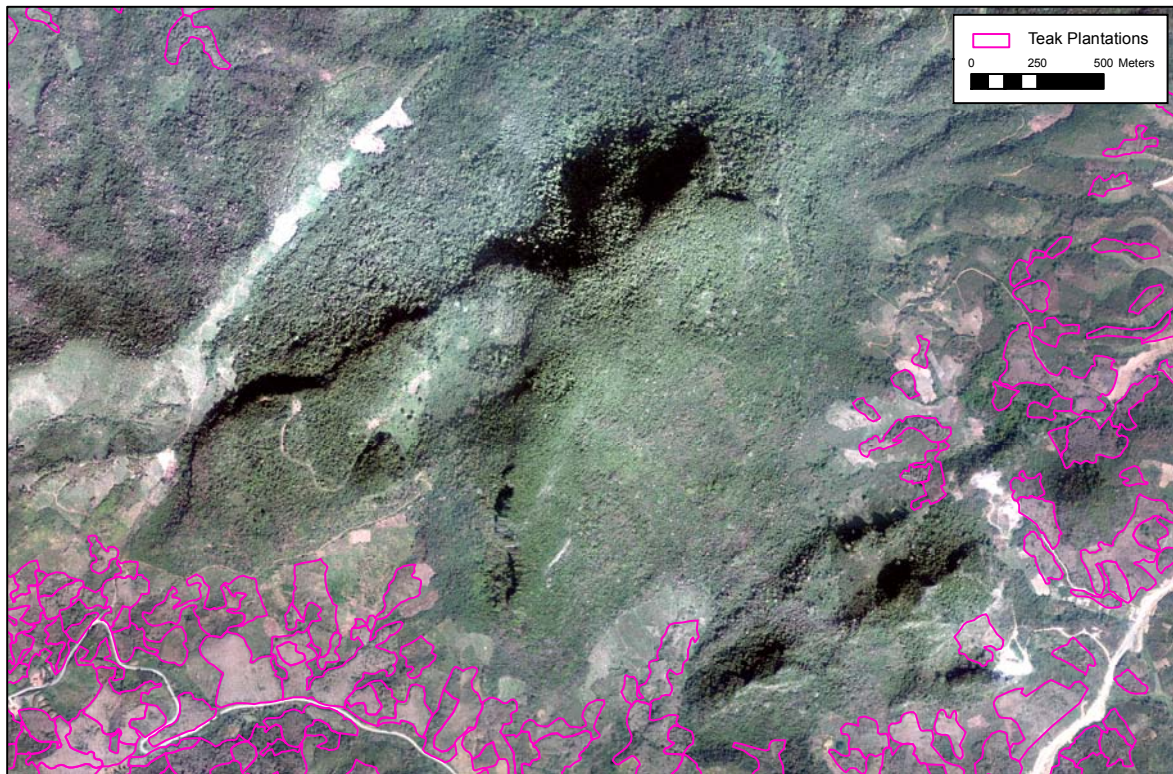
Figure 3: Teak Proximity to Drainage



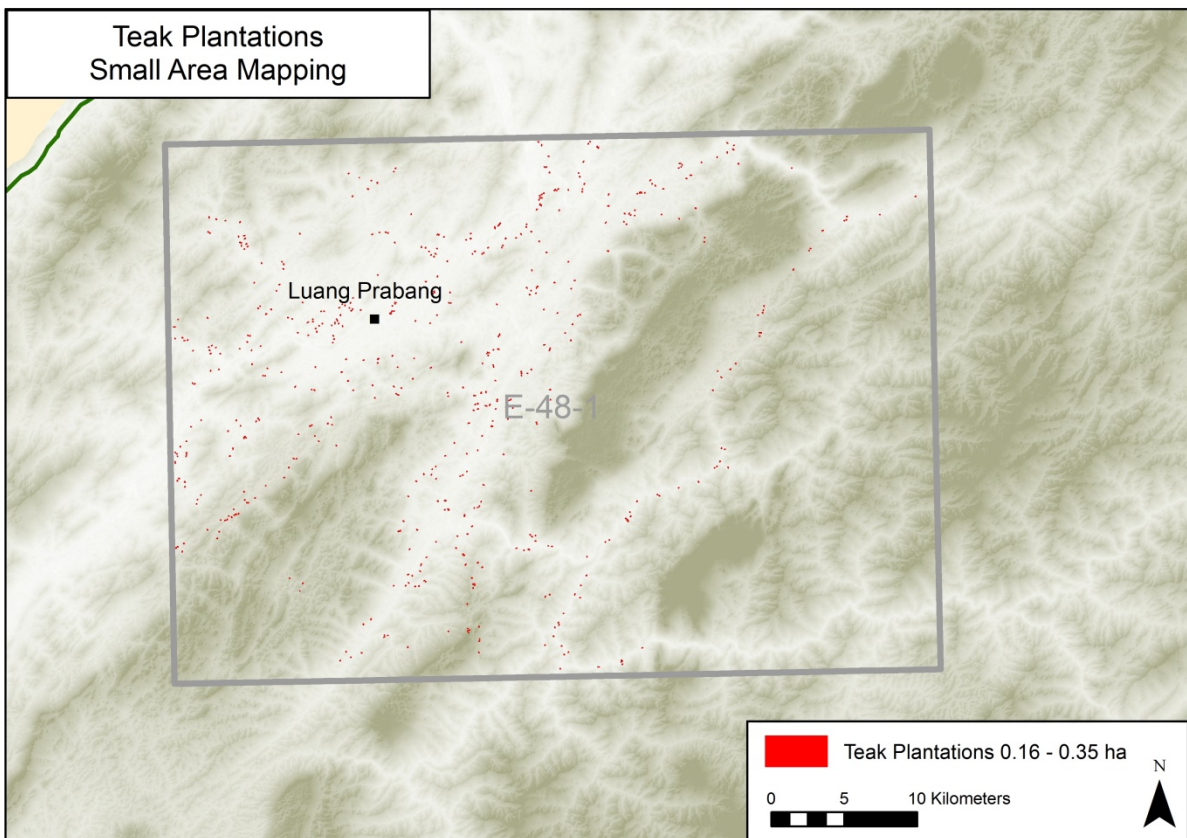
Map 1: Teak Plantations in Luang Prabang Province



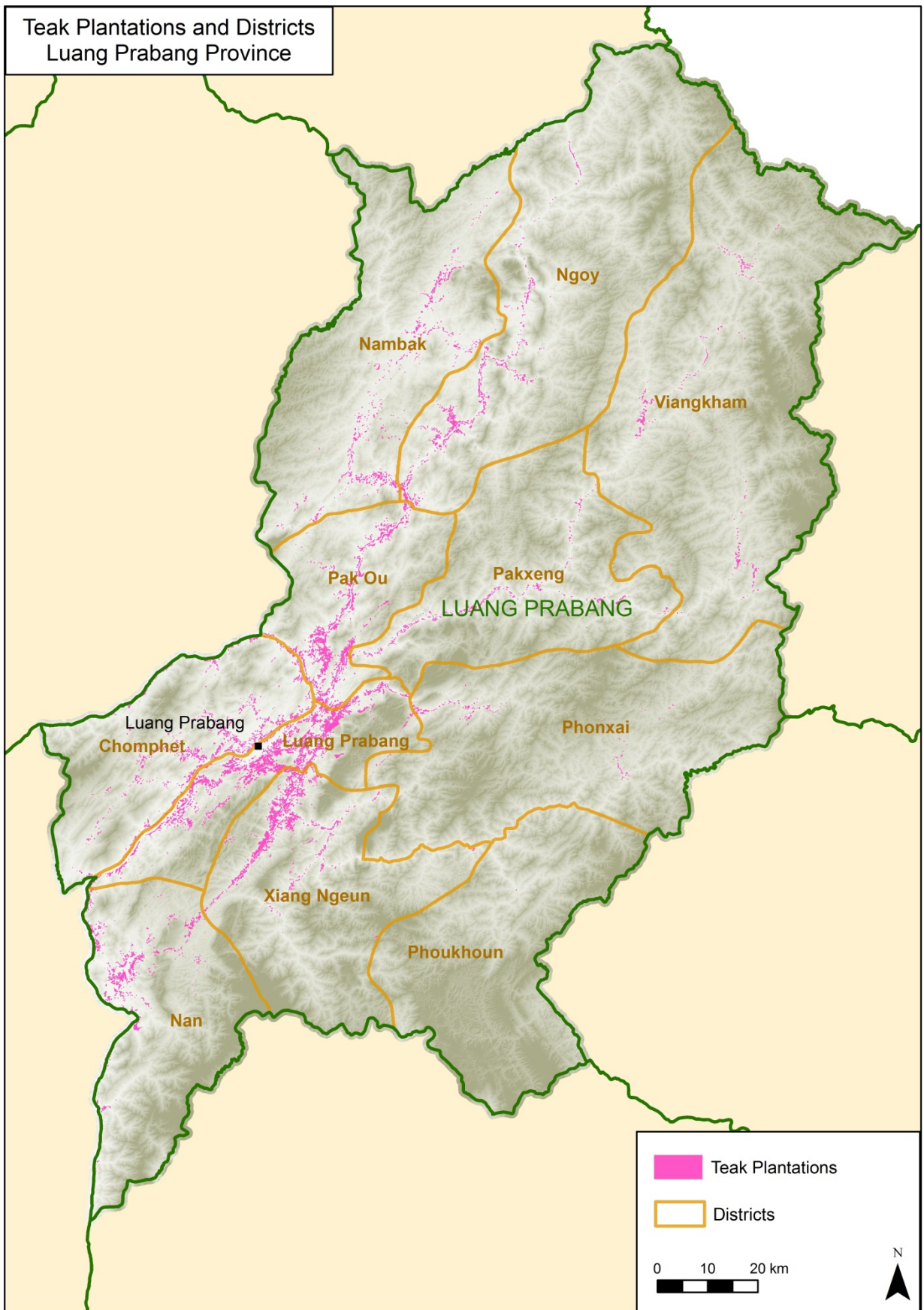
Map 2: Image Shadow



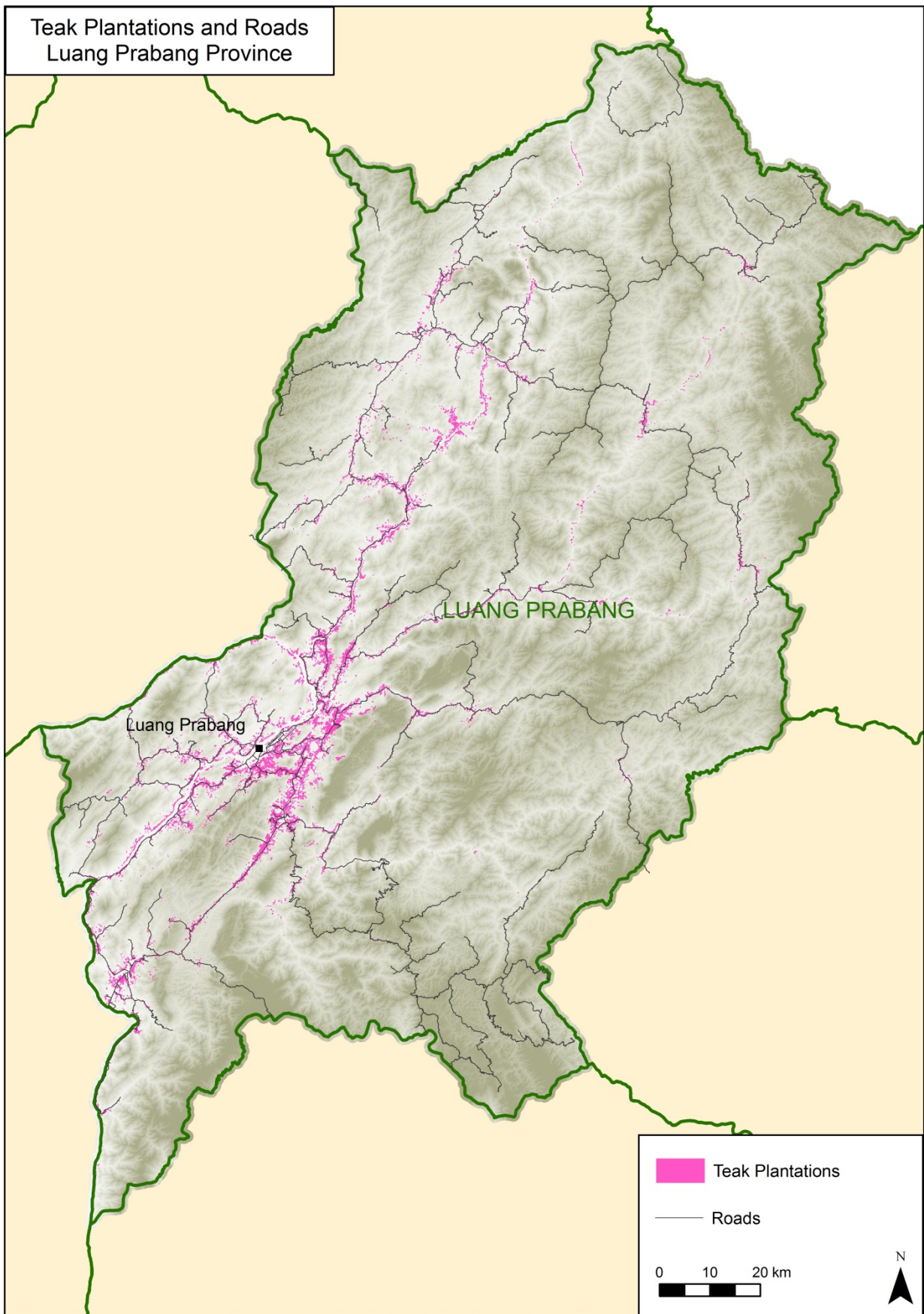
Map 3: Small Area Mapping



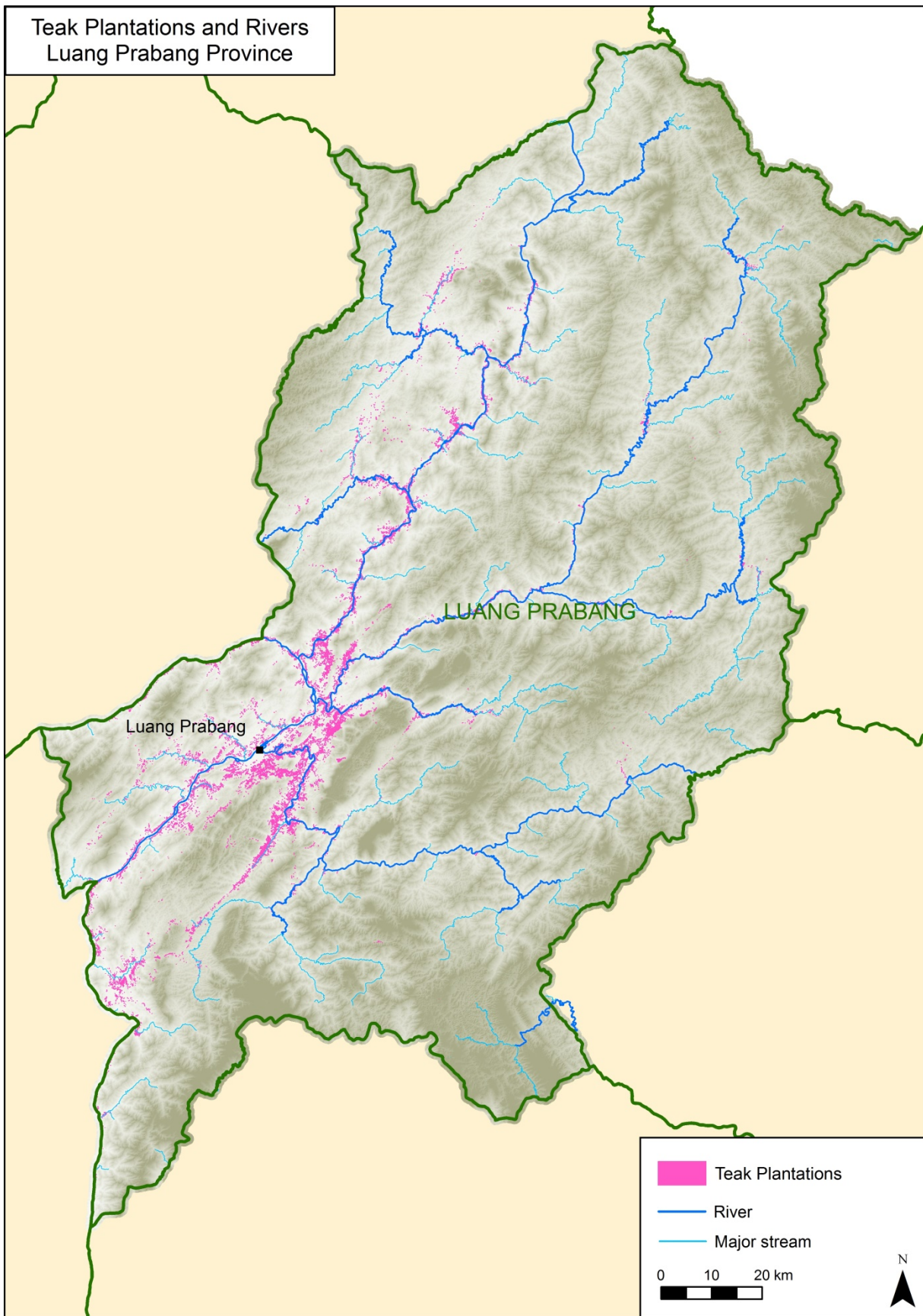
Map 4: Teak Plantations and Districts



Map 5: Teak Plantations and Roads



Map 6: Teak Plantations and Drainage



5 Conclusions

Small area teak plantations can be mapped and characterised with acceptable accuracy using high resolution imagery and skilled operators.

The 15,342 ha of plantations are predominantly small size class with a small percentage in merchantable sizes under current log specifications. The plantations are located in highest densities close to Luang Prabang itself and are in near proximity to roads and major drainage lines.

Estimation of potential wood supply would require further timber inventory and yield forecasting work to build on the current mapping of extent and structure. Estimation of actual wood supply for domestic processing would require determination of availability based on ownership and management intent.

The area of teak mapped is at 2013, the time of image capture. Changes are likely to have occurred to the plantation area since image date from development projects or conversion to other land uses, or to plantation structure from partial harvesting. Quantification of this or future changes would require the mapping to be updated.

6 Next Steps

These outputs provide a snapshot of the extent and structure of the teak plantation resource in Luang Prabang province as at time of imagery capture. This does not provide estimates of the wood supply from this resource. To determine wood supply requires:

1. Standing volume of teak in the plantation resource
2. Growth and yield over time of the existing plantations
3. Availability of merchantable volume to the market
4. Change in the plantation area

6.1 Standing Volume

To estimate standing volume of teak a volume inventory is required. The mapped teak would be the basis for the identification of the population and stratification for the inventory. Field plot measurement would be required. Volume calculations would require biometric functions for height and volume. Merchantable log specifications would be provide estimates of the merchantable subset of the plantation volume.

It is recommended that a field inventory is implemented and the standing volume calculated as the next highest priority.

6.2 Growth and yield

To estimate timber yield over time growth functions of teak at a tree or stand level would be required to model the growth. It is unlikely that specific growth functions for plantation teak in Luang Prabang would be available but it may be possible to use existing growth functions from elsewhere and calibrate them with data from Luang Prabang. One potential problem is the prevalence of partial harvesting of stand dominants and the resulting complex stand structures. Such complexity may make growth prediction significantly harder.

It is recommended that growth functions are investigated for their suitability to model growth and yield.

6.3 Availability of merchantable volume to market

It would be naïve to assume that the maximum merchantable volume in the teak plantation resource will be available to domestic processing in any one year. The plantations are not owned by a single owner where the impact of management decisions can be forecast with relative ease and where issues of wood supply are centrally determined. The plantations have thousands of owners who make decisions on their management based on their personal needs, motivations and opinions. Policies associated with land ownership may either encourage retention of plantations beyond their commercial optimum or see some plantations being used primarily for land ownership and speculation with little or no intention of timber production. Some plantations will fail to reach merchantable size due being planted on the wrong site or through competition from natural regeneration. The subset of actual merchantable volume available is therefore likely to be a significantly smaller subset of the total theoretically available merchantable volume.

It is recommended that a study of a representative sample of plantation owners be undertaken to better understand their management intent of their plantations. From this incentive measures can be identified to maximise volume production for both owners and processors.

6.4 Change in plantation area

There is no information on the annual or periodic increase or decrease of the teak plantation area. Remapping at some point in the future would be requisite to accurately quantify the change in plantation area. To remap the plantations to the same level of detail as in this project would be desirable but may be cost prohibitive. It would be worthwhile to explore analysing the existing mapping with other available, coarser resolution, satellite imagery to test its efficacy in estimating change in plantation area over time.

Capacity and experience in this sort of temporal change mapping currently exists in NuOL. Imagery obtained for the 2016 national inventory would potentially be available for use.

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Appendix

Mapping Instructions

GIS General

Arc Catalog - manage data and files. Like Windows explorer for GIS

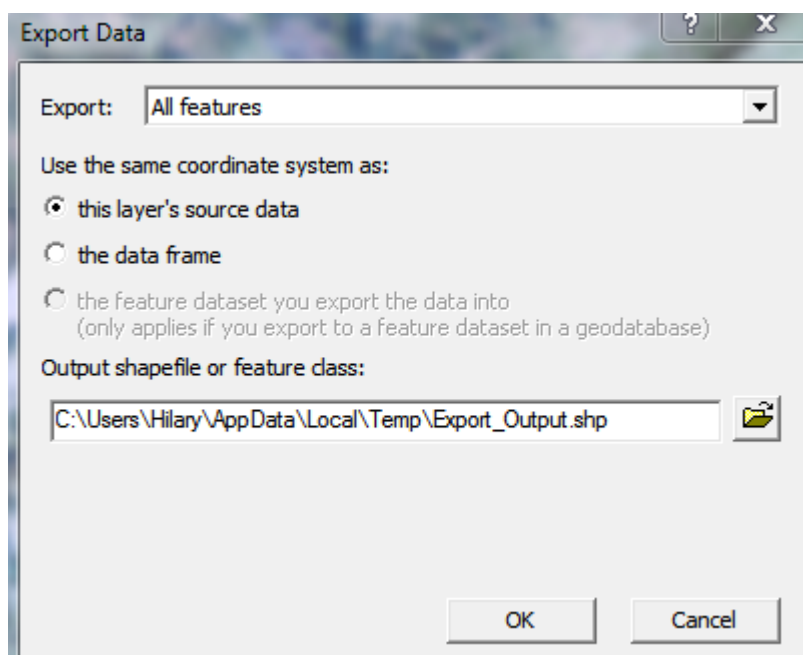
- New file geodatabase - R mouse > New > File Geodatabase
- New feature class - open file geodatabase - R mouse > New > Feature Class


Can also open ArcMap from ArcCatalog

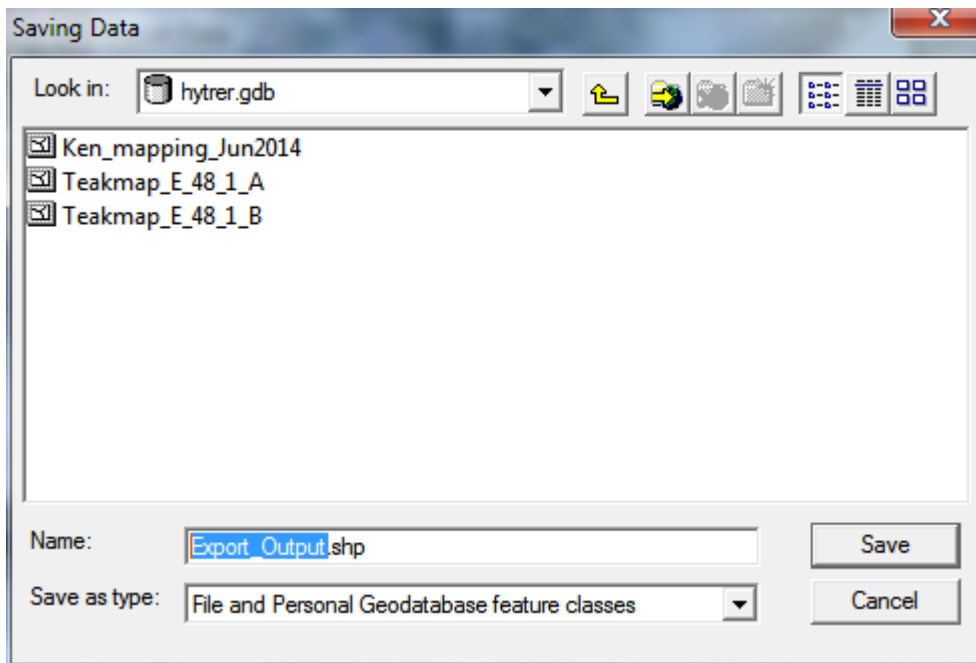
- **!** ArcCatalog sometimes does not update file changes made in ArcMap when both are open. Restart ArcCatalog to update.

ArcMap

- **Toolbars** - add new toolbar - put cursor in toolbar area at top of screen - R mouse to bring up list of toolbars > click toolbar you want
 - To remove toolbar - put cursor in toolbar area at top of screen - R mouse and untick from list
 - Move toolbars by putting cursor on handle on the left of toolbar - L mouse click and hold > move to new location > unhold
- **New feature class** (quick way)
 - Select one polygon from first feature class > R mouse > Export Data




- Click browse button 

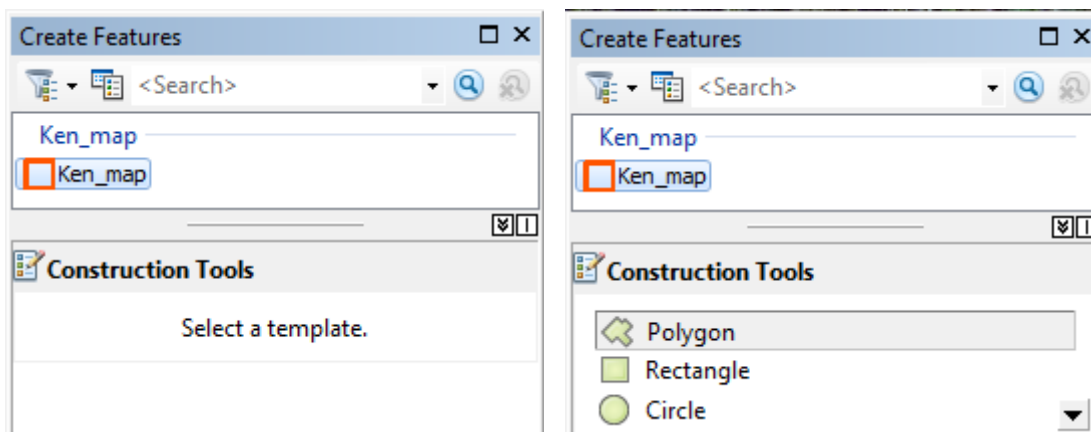


- Change Save as type: to 'File and Personal Geodatabase feature classes'
- Go to geodatabase location in top section
- Change name from 'Export_Output.shp' to new feature class name
- Save > OK > OK to add to project
- Start Editing of this new feature class and delete the original polygon
- Start mapping new teak plantations

- **Editing**

- Start editing a feature class or shapefile - click on it in list on left of screen - R mouse > Edit features.




- Add polygons - open window by clicking on  in Editor Toolbar, which will bring up:



Click on layer in top section ('Ken_map'), then Polygon in bottom section.

- Move cursor to mapview window and start polygon with L mouse click. Move around boundary, clicking L mouse as you go. To finish double click.
- Modify boundary of polygon - double click existing polygon to bring up boundary vertex (square green points on boundary). To move vertex put cursor over > click and hold > move > unhold.

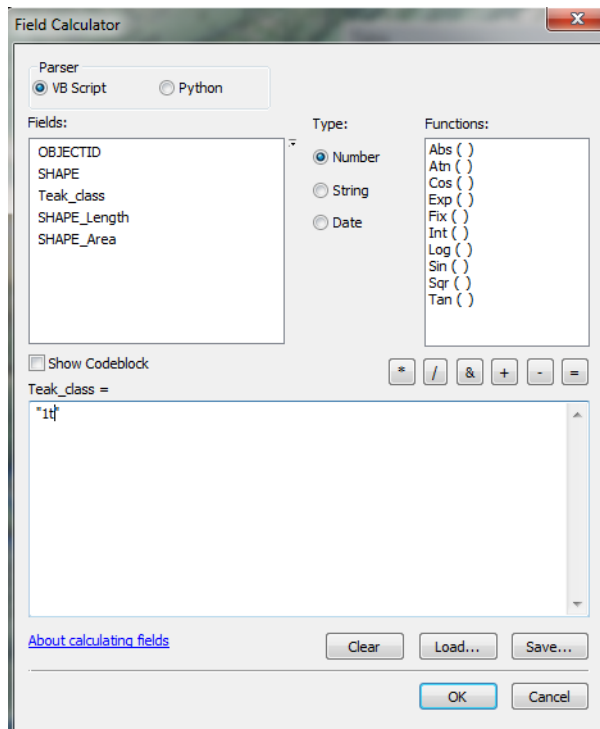
Double click to finish. 

- Cut polygon - select polygon in map window - select cut polygon tool  in Editor Toolbar - draw line across polygon to cut.
- Trace Tool To create new polygon along edge of existing polygon - start new polygon near existing polygon - select Trace Tool  from Editor menu > click on boundary of existing polygon > move cursor along boundary (no clicking!) till end of shared boundary > click > select Line Tool  from Editor menu > draw rest of polygon as normal > double click to finish.
- Add area to polygon - add new polygon and draw around additional area, overlapping




boundaries  > select both polygons  > Editor dropdown menu > Merge.

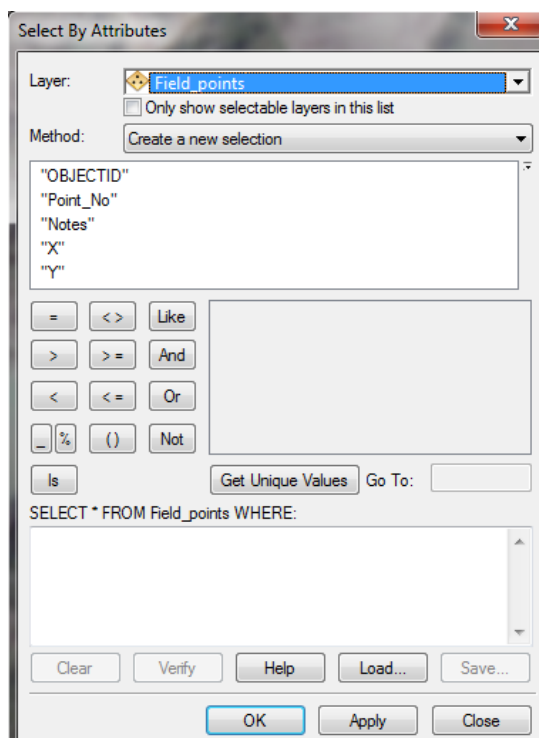
• Attribute Tables

- Open table - R mouse on layer in list > Open Attribute Table
- Add field - click on menu button in top left corner of table > Add Field > enter name and select Type - Short Integer for simple number or Text > Length - change to smaller number than 50.
- Edit table
 - Individual cells can be typed in direct when you are editing the layer
 - If not in Editing mode cells can also be edited by selecting the polygon, or its row in the table, then in the table R mouse on column heading > Field Calculator



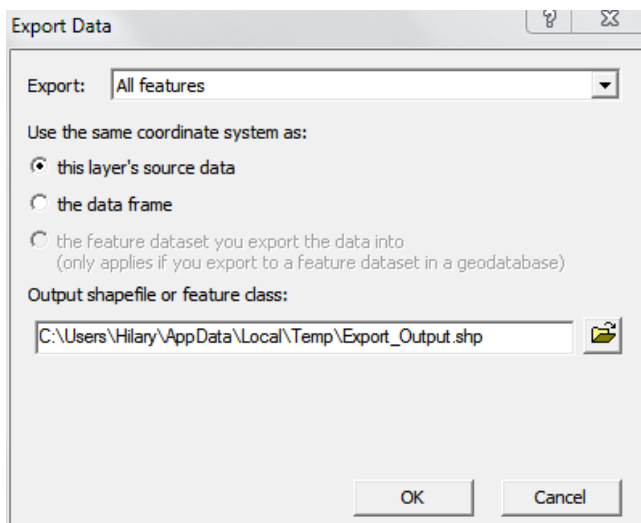
- **Selection**

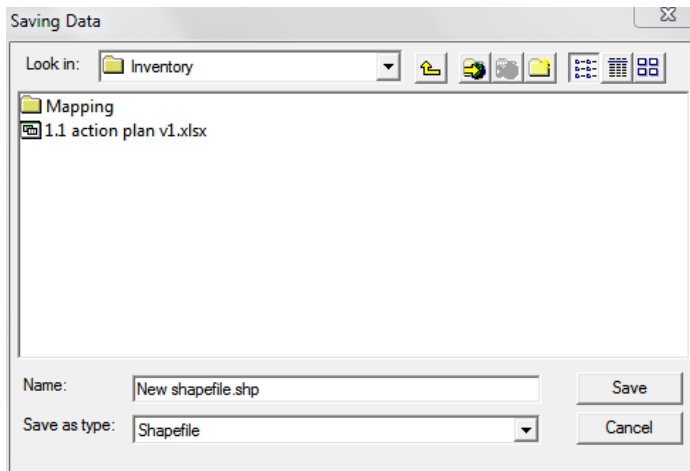
- To select 1 polygon use  in map view or click on one row in Attribute table
- To select a group of polygons use  and draw a box over the polygons
- To select all polygons with the same value in the table use Select by Attributes  which will bring up



- **Sending Data**


- GIS layer old format – **Shapefile**. A shapefile has 3 to 7 individual files with the same first name, e.g.
 - Hydrology.shp
 - Hydrology.dbf
 - Hydrology.shx
 - *Hydrology.prj*
 - *Hydrology.xml*
 - *Hydrology.sbn*
 - *Hydrology.sbx*
- GIS layer new format – **Feature Class** in a geodatabase. It is not possible to identify feature class files outside of ArcCatalog which makes it difficult to send by email.
- It is easiest to send data in shapefile format - R mouse on feature class in list> Data> Export Data >in new window click browse > in next window browse to location, rename and Save as type - 'Shapefile'> Save > OK

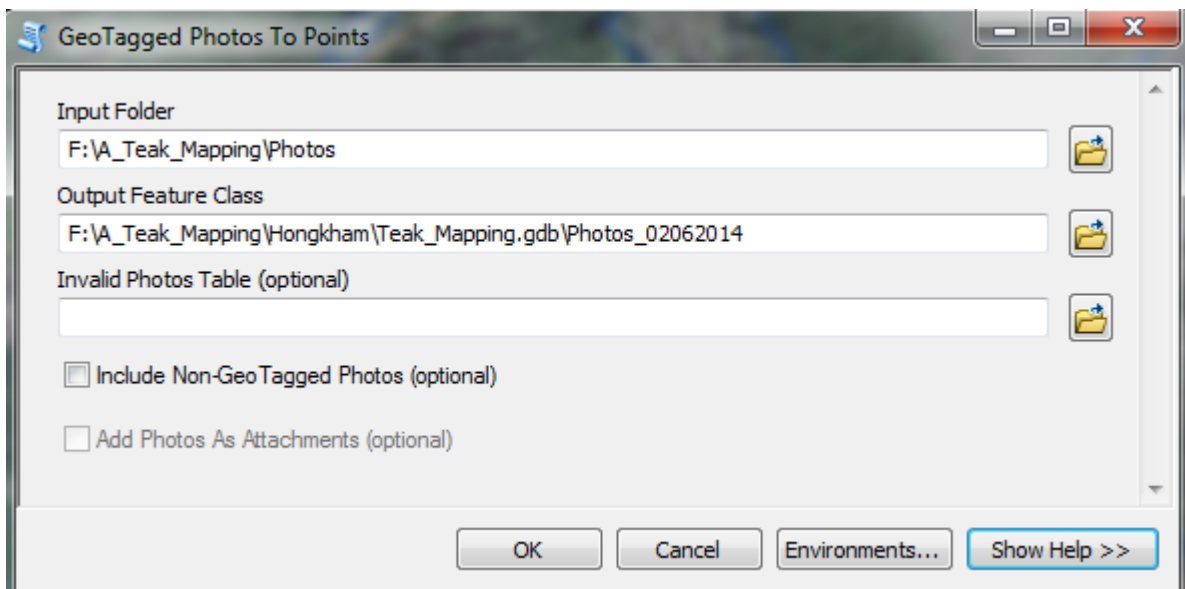




Open email and attach all shapefile files > send.

- **Adding Geotagged Photos**

- Copy photos to computer
- In ArcMap open Toolbox window by clicking 
- Open - Data Management Tools > Photos > Geo Tagged Photos to Points
- Select input folder and name of new feature class of photo points
- Untick both boxes at bottom
- Hit Ok and add layer to ArcMap view



- In map view use Identify and click on photo point to bring identify window


Identify

Identify from: <Top-most layer>

Photo_test

- P 1070190.JPG
- P 1070191.JPG


Location: 201,382.225 2,203,773.709 Meters

Field	Value
FID	0
Shape	Point ZM
Path	F:\A_Teak_Mapping\Photos\P1070190.JPG 
Name	P1070190.JPG
DateTime	2014:06:01 14:37:21

Identified 2 features

- click path row with hyperlink symbol to show photo.

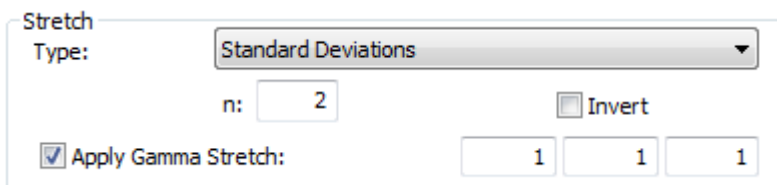
Image Use

- Individual .ecw images are stored in the FINMAP folder in subfolders of 1:100,000 map sheet names - E-48-1, E-48-2
- There are 256 individual images for a complete 1:100,000 map sheet.
- Images are grouped together in raster catalog format  E_48_01 in FINMAP_Imagery/Raster_Catelog.gdb. USE THESE FIRST
- Images are variable in brightness and colour balance. Modify Properties > Symbology and Display to get clearest image

Double click on image name in list to open Properties window

- **Symbology & Display**

- Left pane > RGB Composite
- Right pane > Stretch > Type> Standard Deviations & turn on Gamma Stretch - is recommended.
 - Gamma Stretch – 3 boxes are Red, Green and Blue. To change colour balance change value in boxes. For example
 - To reduce red colour - change number in 1st box from 1 to 0.9 or 0.8
 - To reduce blue colour - change number in 3rd box from 1 to 0.9 or 0.8
 - To change contrast change n: value. Good range is 1.5 – 2.5

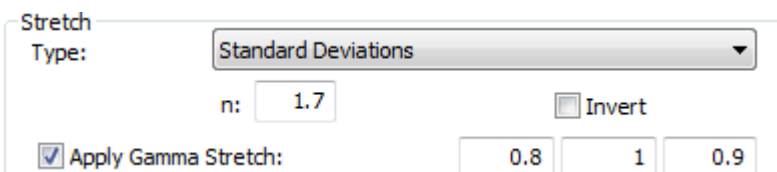


Stretch Type: Standard Deviations

n: 2 Invert

Apply Gamma Stretch: 1 1 1

Change:



Stretch Type: Standard Deviations

n: 1.7 Invert

Apply Gamma Stretch: 0.8 1 0.9

- Stretch > Type > Histogram Equalize will increase contrast Good to use in very dark or hazy areas
- Adjust brightness and contrast - use Display tab or Effects Toolbar.

Teak Mapping Method

1. Classification

Age Class	Size Class (dbh)	Unthinned	Thinned
Young	< 15cm	1	1T
Intermediate	15-25cm	2	2T
Mature	> 25cm	3	3T
Mix diameter	all	4	
50/50	all	5	
Possible	all	6	

Minimum polygon size **0.35** ha = 3,500 m² (SHAPE_area)

2. Existing Mapping

Is there any existing mapping of teak plantations? LPTP has registered plantation data that includes spatial location and inventory data. Use existing mapping as start point for mapping teak. Compare registered teak polygons with image features to start identification.

The important skill for vegetation mapping is pattern recognition. Use information from ground survey to recognise features on the imagery. Use this knowledge to identify teak and estimate size class for areas with no ground survey. This is called 'ground truthing'.

3. Ground Truthing

It is important to make regular field trips to do ground truthing to keep mapping consistent and check areas of uncertainty. It is not necessary to measure plots to do ground truthing. The two main items of information are identification of teak and the dominant size class. This can be done rapidly through observation and practical calibration. Teak is easy to identify with distinct leaf size and flowers, and during the dry season leaf drop it is even easier to identify.

Rapid ground truthing is possible in many areas because the teak is close to the roads. Drive along the roads and identify teak plantations visually. Stop regularly and use a GPS enabled digital camera to take geotagged photos of the teak plantation. Important steps for geotagged photos:

- Allow several minutes for the camera to connect with GPS satellites to get the most accurate location. Do not turn off the camera between locations to maintain connection.
- Carry enough batteries for the whole day use of camera.
- Where possible take close up photos to show tree size. Use something like a hat, or your other hand in the photo, to allow you to estimate size of the trees.
- In the office download the photos and add to GIS to view photos with the mapping imagery (See above section 'Adding Geotagged Photos')

4. Mapping teak polygons (GIS)

- Scan area in a regular pattern at a scale of 1:5,000 – 1:10,000. Identify areas of settlement and agriculture and zoom in on these areas to 1:1500 – 1:3000 to map teak
- Identify teak and draw boundary around whole area of teak regardless of size class
- If there are areas of different tree size and density in the polygon divide into smaller polygons no smaller than 0.35 ha, estimate teak class and label in attribute table
- Adjust image Stretch type (Percent Clip option recommended) and Gamma Stretch band colour if needed to make image clearer for teak identification.
- For areas of shadow on the image it is not possible to map
- Do not overlap polygons
- Check attribute table at the end of mapping for each image mapsheet for incorrect teak class
- Save your edits regularly to avoid data loss.