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Final report

Small research and development activity

project	**Exploration of teak agroforestry systems in Luang Prabang, Lao PDR**
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1 Acknowledgments

The work described in this report was undertaken with funding provided by ACIAR in collaboration between the University of Queensland and the Northern Agriculture and Forestry Research Center (NAFReC, now Upland Research Center) based in Luang Prabang province of northern Laos, in partnership with the Agriculture Research Center (ARC) located at NaPok near Vientiane, Souphanouvong Univeristy (SU, Luang Prabang) and the Northern Agriculture and Forestry College (NAFC, Luang Prabang). Dr Ketsuda Dejbhimon and Ms Thitiporn Pithayawutwinit provided consultancy to this project on the development of laboratory and tissue culture facilities in Laos, and coordinated the first workshop on tissue culture held at Khon Kaen University. Mrs Khonpanh Kanyavong organised a second training course in Laos with the assistance of facilitators from SEAMEO BIOTROP and the Bogor Agricultural University. Dr Outhai Soukkhy and Mr Bounkeing Souliyasack led the work on intercropping of the Nelder wheel. Mr Kikeo Singhalath under supervision of Mr Somphanh Sakanphet had primary responsibility for grafting of the 100 selected teak trees. Mr Somphanh Sakanphet provided overall supervision and coordination of this project in Laos. We also gratefully acknowledge the assistance of Dr John Schiller in linking participants in Khon Kaen University and the Agriculture Research Center (NaPok) with partners in northern Laos.

2 Executive summary

The accumulated smallholder teak woodlots in Luang Prabang comprise a significant forest resource, comprising 60% of the approx. 25,000 ha of teak plantation in this region of northern Laos. FST/2004/057 commenced in 2008 to investigate improvements of the silivicultural management of these woodlots, and was granted a one-year extension from 2012-2013. The work conducted under the small research activity described in this report was undertaken over a 15 month period in Luang Prabang province, ending in June 2013, to support the transition between an existing ACIAR project (FST/2004/057) and a new project (FST/2012/041) with a much stronger focus on teak-based agroforestry systems. Primary research outcomes during the course of the project were:

i) Demonstrated the potential to grow cash crops (peanut, maize, cassava and pigeon pea) with established teak trees when tree densities were 600 stems per hectare or less.

ii) In consultation with Khon Kaen University, available tissue culture facilities and infrastructure in Lao were reviewed – facilities at the Agriculture Research Center were upgraded during the course of this project, plans were drafted for the redevelopment of laboratory space at the Souphanouvong University to create a research facility for tissue culture with teak, and finally detailed plans were developed to create an laboratory at NAFReC for mass propagation of elite teak clones for distribution to smallholder farmers. Successful training programs were run at Khon Kaen University and at ARC.

iii) Improved genetic quality of teak planting stock is a key component to the sustainable production of teak in plantations and woodlots in Laos. A program to select and propagate elite individual trees was initiated during this project, and a total of 100 selected trees were grafted and established in a clone bank and seed orchard. This will provide a source of improved material of clonal propagation via tissue culture, and in the longer-term a source of improved seed.

iv) Interviews conducted with senior staff in the District Agriculture and Forestry Offices in Pak Ou, Nambak, Ngoi, Viengkham and Pakxeng districts indicated strong interest in the growing teak in agroforestry systems rather than in woodlots, a strong need for extension and training materials, and a capacity to collaborate as part of a new project to facilitate establishment of community groups, demonstration trials and extension activities.

This project has provided information used in the development of FST/2012/041 and has supported the development of resources and infrastructure required for the implementation of this new project.

3 Introduction

Teak comprises a major component of smallholder forest tree plantations in northern Laos, with estimates of up to 25,000 ha established in Luang Prabang Province. Smallholder teak woodlots typically range in size from a few trees to 3-5ha, but with most woodlots being less than 0.5 ha. The sale of trees from theses woodlots provide cash income to farmers in rural areas, usually from the thinning of selected individual trees commencing around 12 years after planting. This small grant was linked to an existing ACIAR project (FST/2004/057), and provided additional funding to support and extend activities of this project in Luang Prabang during a one year extension to FST/2004/057, and supported development of new project FST/2012/041 that will commence in 2013. Research under FST/2004/057 primarily focused on the existing teak woodlots in this region – both silvicultural management of these woodlots and socio-economic impacts of woodlots on development pathways in this region of northern Laos, and identified the potential of teak-agroforestry systems as an alternative to teak woodlots, particularly for smallholders with restricted access to land and limited/no non-farm income. Consequently, the primary emphases of this small grant were to maintain and extend capacity to conduct research in Lao partners, commence initial research in the area of agroforestry systems, and investigate potential scope of activities that might be undertaken in a new project with much stronger focus on teak-based agroforestry systems. The objectives of this small research activity were as follows:

1. Investigate impacts of teak on productivity of companion crops when Nelder wheel is intercropped with 4 agricultural crops.
2. Develop capacity in tissue culture of teak
3. Explore opportunities for teak-based agroforestry systems in more remote regions of northern Laos
4. Infrastructure development through improvement of facilities at the Agroforestry Research Station, and provision of additional pruning and measurement equipment.

The following activities were completed under this small grant during the 15 month period to June 2013:

i) Intercropping in Nelder wheel established on campus of the Northern Agriculture and Forestry College (NAFC) – preliminary trails were conducted in 2012 to assess potential of establishing crops under the existing trees, and full trial was established in 2013 (preliminary results are reported here).

ii) Training and scoping activities to support the development of facilities and capacity for the propagation of teak by tissue culture – linkages were developed with Khon Kaen University (KKU), preliminary training was conducted at KKU, team from KKU visited Luang Prabang and Vientiane to review existing tissue culture facilities and provide recommendations on requirements for both the improvement of existing facilities and development of a new laboratory, and provision of resources to repair tissue culture laboratory at Agriculture Research Center (ARC, at NaPok), and commence redevelopment of laboratory space at the Souphanouvong University (SU).

iii) Selection and grafting of individual teak trees with superior phenotypes – total of 100 trees were selected in seven different locations of Luang Prabang province, and all trees were grafted and established in a clone bank and/or clonal seed orchard at the Agroforestry Research Station (part of the Northern Agriculture and Forestry Research Center, NAFReC) that is located at Thong Khang.

iv) Interviews were conducted with DAFO (District Agriculture and Forestry Office) in most of the northern districts of Luang Prabang province to discuss planting of

teak, assess interest and support for new project focused on teak-based agroforestry systems and determine opportunities for collaboration.

v) Provision of funds upgrade water supply and facilities at the Agroforestry Research Station at Thong Khang and to purchase measuring (i.e. vertex) and pruning equipment for NAFC and additional GPS units for the partner organizations in Laos.

4 Intercropping of Nelder Wheel at NAFC

Preliminary work was undertaken during the 2011 wet season to assess the potential to grow crops under existing teak trees that had been planted in 2008 in a Nelder wheel on the campus of the Northern Agriculture and Forestry College. An unreplicated trial was conducted in three sections of the wheel (i.e. area between four adjacent spokes of the wheel) to: a) evaluate any potential negative impacts on the existing trees resulting from cultivation prior to planting the crops, and b) determine if peanuts, cassava and a native ginger (galangal) could be established successfully on this site. This initial trial provided no indications of any adverse effects on the established trees that may have been caused by establishment of crops on this sites, and further both peanut and cassava crops were able to be established and grown successfully in the Nelder wheel. Prior to the commencement of the 2013 wet season, the entire area (from approximately 4th tree in each spoke to the outside of the wheel) located between trees in the Nelder wheel at the College was cultivated twice with agricultural tractor and offset disk plough in May 2013. Replicates of cassava, peanut, pigeon pea and maize were sown on 25/5/2013 at standard plant densities for each crop, using varieties commonly used in the region, or which has been previously evaluated in studies at the NAFC. Height of each crop was measured at the mid-point between established trees, at stockings from 637 to 106 stems per hectare. Additional data will be collected at the end of the growing season to evaluate yield potential under established teak. Preliminary results (i.e. plant height, Figure 1) indicate that it is possible to successfully intercrop 6-year-old teak, where the teak is planted at relatively low initial stockings (i.e. 600 sph or less). Below stockings of 400 sph, there does not appear to be any adverse impacts of the established trees on the developing crops (Figure 1). However, interactions of the trees and the crops will be more fully assessed once all data on the crop yields is available at the end of the growing season. This experiment will be repeated across years under the new project (FST/2012/041) to more fully assess the potential for intercropping through to 8-10 years after planting of the teak. Nevertheless, these preliminary results are promising, and indicate that given appropriate tree densities intercropping with teak might be practiced much longer than the first 2-3 years after planting of teak (i.e. current practice).

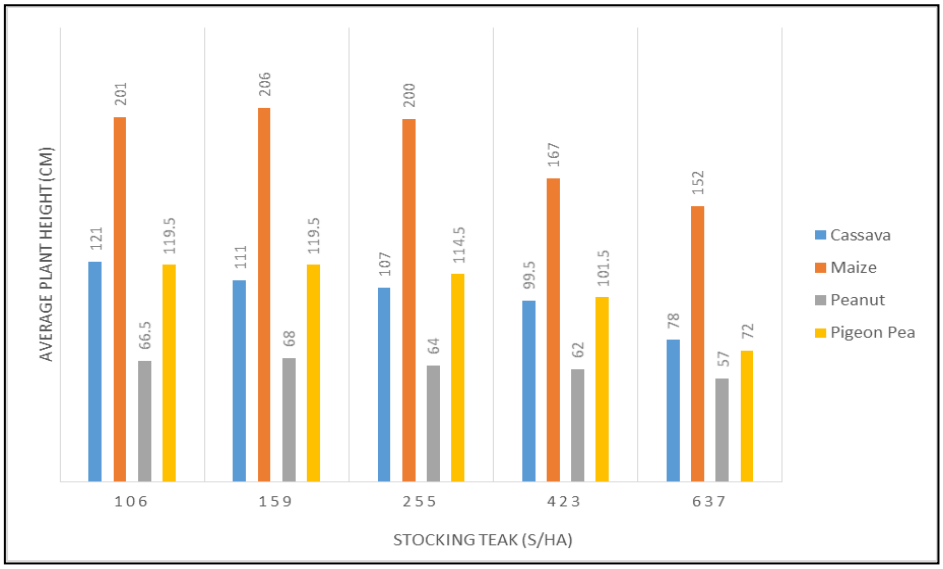

Figure 1: Average plant height (cm) two months after sowing of four crops interplanted into the Nelder wheel at the Northern Agriculture and Forestry College.

5 Tissue Culture

Tissue culture has been applied successfully to the rapid vegetative propagation of selected clones in many forest tree species, including teak. In Laos, tissue culture offers the potential to make improved planting stock of teak available rapidly to smallholder farmers at a cost similar to existing unimproved planting stock. Distribution of improved planting materials can be achieved rapidly through the DAFO nurseries (currently major supplier of teak seedlings in most districts), and will facilitate reduction in initial planting rates through deployment of teak with improved stem straightness and form.

Laboratory and tissue culture facilities that might be used for teak exist within the Agriculture Research Center (ARC) located at NaPok (outside Vientiane), and laboratory space exists within the forestry department of the Souphanouvong University. However, neither group had previously any experience in the propagation of teak or tree species using tissue culture. Further, the air-conditioning units installed in the growth rooms of the tissue culture laboratory at the ARC were broken, and ceiling needed to be replace to make facility vermin-proof and sterile. At the Souphanouvong University equipment had been provided when the new campus was constructed; however, it had never been used for tissue culture and no facilities existed to grow plants once transferred into culture.

Under the scope of this small grant the following activities have been completed:

i) Links were established with Khon Kaen University in Thailand, in the Agriculture Department. Initially Dr Mark Dieters and Dr John Schiller visited KKU to discuss opportunities for collaboration and discuss provision of training for Laos partners. As part of these discussions Dr Ketsuda Dejbhimon agreed to coordinate provision of training and consultancy services to this project.

ii) KKU organized and ran a two week introductory training course in tissue culture for 12 staff from Laos, March 20-29 2012. The following people from Laos attended this course in Khon Kaen: – Bounkieng Souliyasack and Vilaphob Phouthone (NAFC); Somphanh Sakanphet, Touy Sengkamdy and Vanpheng Bounkhong (NAFReC); Soukphathai Khosimeuang, Vilalak Saphangthong and Amphai Souvannalath (ARC); and ounheuang Channang, Khanaavanh Phomlasoud and Souksamone Phangthavong (SU).

iii) Subsequently ARC (independently) arranged a follow-up training in the tissue culture of teak at NaPok from May 27 to June 1 2013 that was supported indirectly by this small grant through the attendance of project staff and repairs to the tissue culture facilities at NaPok. Facilitators for this training course came from Indonesia (SEAMEO BIOTROP and the Bogor Agricultural University), and provided specific information on the application of tissue culture to the propagation of teak. There were 16 participants from NAFRI (Agriculture Research Centre and Upland Research Centre), Ministry of Science and Technology, National University of Laos, and Souphanouvong, Savannakhet and Champasack Universities – three of which are participants in this project.

iv) Funding provided by the small grant allowed ARC to purchase chemicals and other consumables required for tissue culture of teak. Preliminary work was undertaken under supervision by advisor from Indonesia in May 2013, and grafted trees (refer to subsequent section) were sent from NAFReC to ARC in June 2013. Work is a very preliminary stage, and no results are yet available.

v) Team form KKU (Dr Ketsuda Dejbhimon and Ms Thitiporn Pithayawutwinit) visited Luang Prabang (11-15 February 2013) and Vientiane (27 March 2013) to review the existing tissue culture facilities at ARC and SU, review infrastructure at NAFReC that might be used , and make recommendations relating to

repairs required at ARC, upgrades that are required at SU to convert existing laboratory space into a functioning tissue culture laboratory, and provide recommendations regarding the location and design of a new tissue culture laboratory at the Hauy Khot headquarters of NAFReC in Luang Prabang province. The primary recommendations were:

i. Immediate repair of air-conditioning units for the growth room in the ARC tissue culture laboratory, as it was impossible to maintain suitable temperatures without air-conditioning.

ii. Replace seeding in ARC tissue culture laboratory to make vermin proof, and seal rooms so that they could be made clean and sterile. (Note: repairs indicated in points i and ii here have now been completed using funds provided by this small grant).

iii. Split existing laboratory at SU into three rooms by the construction of new internal walls and doors, to form separate preparation room, transfer room and growth room. Also, requirements for replacing windows, and purchase of additional equipment were detailed. Based on the recommendations plans were drafted (Figure 2), and quote obtained for the required work. Funds were provided to commence the modification of the laboratory space.

iv. Redevelop existing office and dormitory space at NAFReCs headquarters at Huay Khot into a tissue culture laboratory. Based on recommendations, plans have been drafted (Figure 3) and quotes obtained. A complete list of equipment and consumable was also provided. This was used to assist the development of project proposal for FST/2012/057. All preparations are now in place for the development of these new facilities under the new project (FST/2012/041), as soon as project agreements are finalized and funds can be sent to Laos from Australia. However, given drop in the exchange rate (AUS/US $), changes will probably be required to planned development, as this equates to approximately 15% reduction in funding.

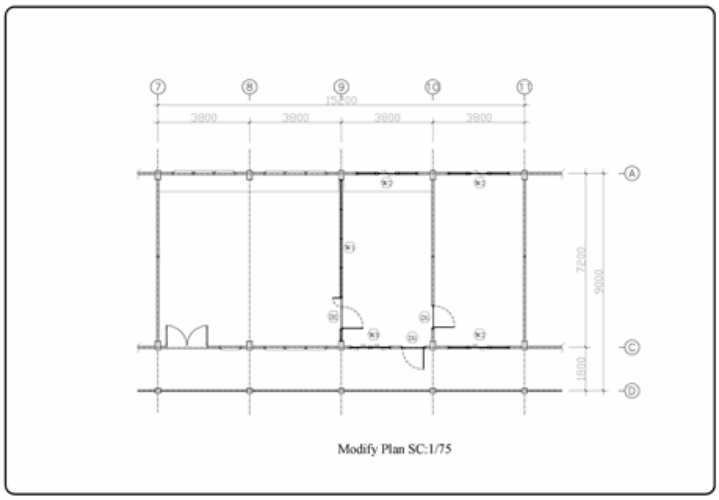

Figure 2: Plans for proposed redevelopment of laboratory space at Souphanouvong University to convert existing laboratory space into a tissue culture facility (preparation room, transfer room and growth room). Note: some of this work has now been completed with funding from this grant, and remaining work will be completed as part of FST/2012/041.

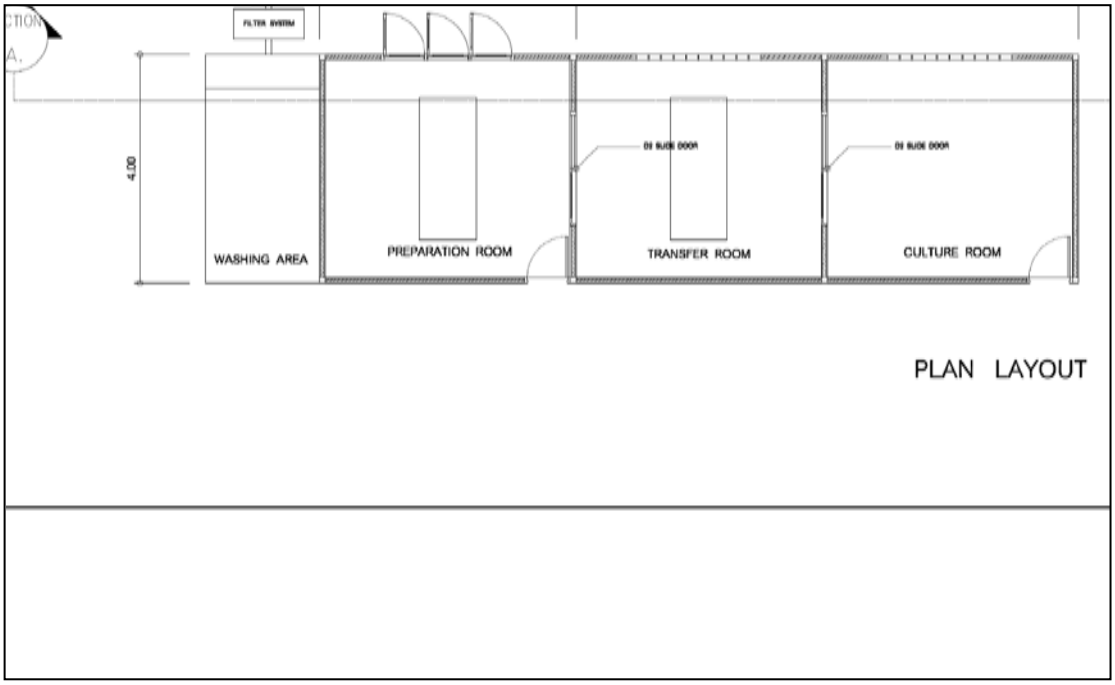

Figure 3: Proposed design of new tissue culture laboratory at NAFReC (Hauy Khot).

6 Selection and Grafting of Elite Teak Trees

The availability of genetically improved planting stock of teak in Luang Prabang is fundamental to the long-term viability of a teak plantation program. Little genetic improvement of teak has been conducted with teak, and smallholders continue to use unimproved sources of planting stock. Teak is not endemic to the Luang Prabang region of northern Laos, and it is assumed that multiple introductions of seed have occurred from natural stands in neighbouring provinces of Laos (i.e. Bokeo and Xiaganbouli). As such, the existing teak stands in Luang Prabang are likely to contain a diverse sample of the genetic variation present in the natural stands of northern Laos. Further, there are some stands known to be established with seed from Myanmar.

Under FST/2004/057 attempts were made to propagate teak by cuttings, using shoots from branches collected from mature trees selected in the field. This involved selecting 50 elite trees, collecting branches from these trees, setting as 'sticks' under mist in the nursery, and then setting shoots produced as cuttings. Although this procedure has been used successfully in Malaysia (Monteuuis and Goh, 1999), the success rate was very when applied in Laos – less than 10 successfully rooted cuttings were obtained in FST/2004/057. Nevertheless, serial propagation of the few successful cuttings is expected to have a higher strike rate (Olivier Monteuuis, pers. comm.).

Genetic diversity represented in the Luang Prabang teak plantations is being depleted as smallholders selectively harvest the best trees from their woodlots. This management strategy is not only sub-optimal from a silvicultural perspective (as being addressed in FST/2004/057 and FST/2012/041) but also depletes the genetic integrity of these plantations as the best trees are removed, leaving only the poorest (slow growing, poorly formed) trees to produce seeds for the next generation. Therefore in order to assemble a diverse sample of elite trees from the Luang Prabang teak plantations, and to provide source of genetically improved material for use in FST/2012/041, 100 teak trees with superior form (good stem straightness and cylindrical (non-fluted) boles) and good relative vigour (i.e. larger than surrounding trees) were selected phenotypically in diverse regions of Lunag Prabang province (Appendix 1). Each selected tree was marked, and geo-tagged using a hand-held GPS, mapped and photographed (Figure 4). Branches were collected from each selected tree just prior to the start of the 2013 wet season, and grafted onto bare-root 'stumps' that were when the grown in polybags (Figure 4) for 3-4 months in the NAFReC nurseries. Success rates exceeded 70% for most clones.

Grafted plants planted in June 2013:

- Clone bank – five grafted plants per clone, as single row, at spacing of 5 x 2m. Progressive thinning is rows to retain best two trees of each clone will lead to final stocking in clone bank of approximately 5 x 5m. Aim to intercrop this area with pigeon peas – both to determine potential and to fix nitrogen.
- Clonal seed orchard – 3 grafted trees of each clone, planted along contour at spacing of 6 x 3m. Aim to progressively remove trees and clones, so that only the best clones are retained for seed production in approximately 5-6 years. Clonal seed orchard was interplanted with Stylo.
- Hedges – potted stock of each clone retained in nursery at Hauy Khot (NAFReC) and transferred to NaPok (ARC). These plants will be maintained as hedges and used to source of material for propagation of clones by tissue culture and cuttings.

On-going careful maintenance of these plantings of grafted trees is important to ensure that the root-stocks do not produce new shoots that replace the grafts.

Under new project (FST/2012/041) additional trees will be selected and grafted to enhance the genetic resources available to this project. Ideally this will also include selection of trees from the natural stands; however, collection of grafting material from very large trees may not be possible.

Figure 4: Left: Somphanh Sakanphet beside an elite teak tree selected in Luang Prabang. (Photographer: Mark Dieters). Right: Successful teak graft (Photographer: Mark Dieters)

7 Exploration of Opportunities for Teak-Based Agroforestry Systems

Research activities conducted under FST/2004/057, for logistical reasons, have been primarily restricted to areas located within approximately 100 km of Luang Prabang city; i.e. in Luang Prabang, Xieng Ngeun, Nan and Chomphet districts of Luang Prabang province (Figure 5). These districts also represent the main location where smallholders have established teak woodlots in the province. However, the northern districts of Luang Prabang province (Figure 5) include some of the least developed regions of Laos, characterized by low incomes, high dependence on subsistent agriculture and non-timber forest products harvested from natural forests and seasonal food shortages. Development activities in these regions are indicated as a high priority by the Government of Laos, along with increased area forest cover and reduced land degradation. Teak-based agroforestry systems offer the potential to address these government priorities – reduction in poverty, reduced dependency on natural forests, increased forest cover, improved environmental sustainability.

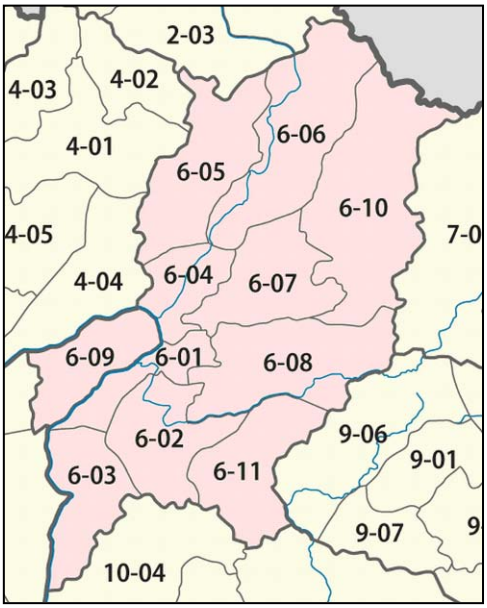

Figure 5: Districts of Luang Prabang province (6) of northern Lao PDR – 6-01 = Luang Prabang, 6-02 = Xieng Ngeun, 6-03 = Nan, 6-04 = Pak Ou, 6-05 = Nambak, 6-06 = Ngoi, 6-07 = Pakxeng, 6-08 = Phonxay, 6-09 = Chomphet, 6-10 = Viengkham and 6-11 = Phounkhone districts respectively (Source: http://en.wikipedia.org/wiki/Districts_of_Laos). NB: Spelling of district names vary depending on transliteration from Lao to English and/or French.

Under this component of the small grant, District Agriculture and Forestry Offices (DAFO) in Pak Ou, Nan, Ngoi, Nambak, Viengkham and Pakxeng districts (Figure 5) were visited by Somphanh Sakanphet, Kikeo Singhalath, Jonathan Newby and Mark Dieters from February 18-22 2013. DAFO staff (usually the director or assistant director) were interviewed to determine: current and expect level of teak plantation activity in the district, knowledge of the impacts of stocking rates on the growth of teak, interest within the district in agroforestry systems involving teak or other tree species, existence of other related projects (past or current) in the district, status of the land allocation system,

potential for collaboration in proposed new project (FST/2012/041). Key outcomes are summarized below:

1. Woodlots of teak occupy a relative small component of the landscape in regions distant from Luang Prabang city, with Pak Ou and Pakxeng districts having the largest estimated areas of teak of those visited. Consequently, there is little opportunity to expand the network of on-farm thinning trials into districts other than Pak Ou and perhaps Pakxeng. Establishment of demonstration sites may therefore be the most practical option in many of these northern districts.
2. The overall level of knowledge of teak silviculture was poor, e.g. some DAFO were still recommending initial stocking rates as high as 2500 stems per hectare. Source of information appeared to primarily come from traders. Farmers were seeking information on how to grow teak. DAFO were the primary source of planting stock. Demonstrates need for involvement DAFO in the next stage of ACIAR's work in the region and requirement for extension materials.
3. Non-timber forest products (NTFP) are an important component of smallholder incomes, with the harvesting and processing of broom grass being a major source of income in many of the districts visited. NTFP products were primarily exported directly from Luang Prabang province to China. Many NTFP are becoming increasingly difficult to harvest from natural stands. Broom grass demonstrates the potential for production in gardens and/or in combination with teak as a component of agroforestry systems.
4. There was a high degree of interest and support for teak-based agroforestry systems. Potentially, the training centers run by DAFO may be usefully engaged to assist in training and extension activities and/or the establishment of demonstration trials. As follow-up DAFO staff were invited to meetings in Luang Prabang to discuss outcomes of FST/2004/057.
5. Land allocation has not been completed in many of these districts. As such, land-use is determined primarily by community agreement, rather than at an individual level. This suggests a need for greater involvement of communities rather than individual smallholders in the new project – establishment of demonstration trails with community or farmer groups on land allocated by village, rather than approach adopted in FST/2004/057 where the project partnered with individual farmers.

It was not possible to visit Phonxay district at this time. Nevertheless, it is expected that interest and capacity for involvement in FST/2012/041 will be similar to neighbouring the districts of Viengkham and Pakxeng. Further, the current level of project activities in Chomphet district (west of Mekong River) is limited to only one village (Ban Sanok), and so in the future we should aim to expand the level of project activities in Chomphet district. It also was not possible to visit other provinces (i.e. Bokeo and Xiangbouli) as originally planned, and visits to PAFO (Provincial Agriculture and Forestry Office) and DAFO and other projects working in these provinces will be important within the first six months of FST/2012/041 to determine prospects and opportunities for collaboration and cooperation.

8 Capacity Development

Funding from the small grant allowed improvements to infrastructure in Lao partner organizations. The Agroforestry Research Station at Thong Khang is critical to the implementation of ACIAR forestry project FST/2012/041 in northern Laos – this where the teak clone bank and seed orchard were established in 2013, plus the location of Nelder wheels established in 2008 and 2013, and thinning trials established as part of FST/2004/057 are located in smallholder woodlots in the neighbouring villages. The project provided funds for the following up-grades and/or repairs to the research station: replacement of water pump at spring, pipes and water tank to supply water to the station (Figure 6); repairs to the roof and ceiling, and repaint the dining facility (Figure 7); plus repairs and upgrade of bathroom/toilet facilities in dormitory (Figure 8). Additionally, as indicated section 5 (Tissue Culture) funds were provided (partially from this project) to: replace air-conditioning units and the ceiling in the tissue culture facility at ARC (NaPok), and commence the construction work at Souphanouvong University to convert existing laboratory space into a tissue culture facility.

Additional equipment purchased and supplied to partners in Laos include:

- Vertex hypsometer (NAFC)
- Handheld GPS units (NAFC and NAFReC)
- Pruning saws (NAFReC and NAFC)
- Pole saw (NAFC)
- pH meter (ARC)[1]

Funding also allowed purchase of consumables, chemicals and glassware required for tissue culture of teak at ARC and SU. This has allowed initial experimentation on teak, and ARC to host training workshop on the propagation of teak.

Figure 6: New pump installed on spring at Thong Khang to supply water to the Thong Khang Agroforestry Station (Photographer: Mark Dieters)

[1] *Purchased – but not yet delivered to ARC from Australia.*

Figure 7: Renovated dinning facility at Agroforestry Research Station (Photographer: Mark Dieters)

Figure 8: Somphanh Sakanphet and Gary Sexton in front of renovated dormitory at the Agrforestry Research Station (Photographer: Mark Dieters)

9 Conclusions and recommendations

This project was comprised of work undertaken both as an extension of FST/2004/057 (extended for one year until June 2013) and to link FST/2004/057 with a new project (FST/2012/041) that will commence in the second half of 2013. As such, work focused on activities that would facilitate the development and implementation of a new project with strong focus on teak-based agroforestry systems: preliminary investigation of intercropping as part of existing Nelder wheel; training in tissue culture and preparations for the development of tissue culture facilities; selection and grafting of elite teak trees; and capacity improvements.

9.1 Conclusions

- Preliminary experiments on the establishment of crops under existing teak trees in the Nelder wheel, indicate that a range of high-value crop species can be established successfully under teak. Impacts of 6-year-old teak on developing crop appear to be relatively small where the stocking of the teak is 400 stems per hectare or less. More detailed evaluations will be possible once yield data is available on the crops when harvested at the end of 2013.
- External review of existing facilities for tissue culture in Laos highlighted:
    - Capacity of staff that currently exists within ARC at NaPok
    - Identified relatively minor works that were required at ARC to improve the existing facilities. This work has now been completed, and preliminary experiments have commenced on propagation of teak.
    - Need to build separate preparation, transfer and growth rooms within existing laboratory space at the Souphanouvong University, in order to make space useful for tissue culture research. This work commenced during the period of this small grant. Conversion of laboratory space will be completed under the new project.
    - Capacity to share existing equipment amongst existing and planned laboratories at Souphanouvong University to minimize requirements for the purchase of new equipment.
    - Potential to convert existing office space at NAFReCs Hauy Khot facility into a tissue culture laboratory for teak; however significant costs will be involved in making required changes.
    - Opportunities for provision of training in tissue culture, and identification of existing staff at NAFReC and Souphanouvong University with both aptitude and interest in tissue culture. Two training programs have now been completed – one in Thailand at Khon Kaen University and the other in Laos at the Agriculture Research Center.
- One hundred teak trees were selected in seven different locations surrounding Luang Prabang city, with the aim of preserving a diverse sample of teak, and providing improved teak that could be used for future tissue culture research and production of seed. Grafting success exceeded 70%, and grafted trees have now been established in a clone bank and a clonal seed orchard at the Agroforestry Research Station (Thong Khang), and as hedges at both Hauy Khot and NaPok.
- Surveys of DAFO staff in northern districts of Luang Prabang province indicate need to strong collaboration with these district offices in the next phase of ACIAR research with teak in this region. There is strong need to training and extension to support the adoption of appropriate silviculture for teak in this region. All DAFO

staff interviewed indicated strong interest and support for a new project investigating teak-based agroforestry systems. Areas requiring further evaluation/exploration are:

  - Community, village or farmer groups as avenue for the establishment of demonstration trials in more remote regions of Luang Prabang province;
  - Opportunities for the involvement of DAFO training centres in extension and training activities;
  - Potential for establishment of additional thinning trials in Pak Ou district;
  - Phonxay district – level of interest and capacity be involved in new project;
  - Bokeo and Xiangbouli Provinces – opportunities for collaboration with PAFO/DAFO and related projects working in these districts.

- Relatively minor investments to improve infrastructure will have major impacts on the future activities in the region:
  - Upgraded tissue culture facilities at ARC have been used for training program and preliminary tissue culture work with teak.
  - Upgraded water supply at Thong Khang has allowed new research activities to be conducted on the station in 2013 (with peanuts). These are other improvements will greatly improve capacity to undertake agroforestry research on this station.

9.2 Recommendations

- Intercropping of established teak shows considerable promise. Need to repeat experiments in College Nelder wheel over the next 2-3 years, to determine viability of intercropping under teak through to at least 8 years after the teak trees are planted.
- Existing facilities at ARC and SU be developed/upgraded as soon as possible, to provide laboratories that can be used conduct preliminary research to apply/modify protocols obtained from Indonesia and Thailand for the propagation of teak. It is expected that ARC will take lead role in the new project, and staff will assist development of new laboratory at NAFReC.
- A tissue culture laboratory developed at NAFReC will logically focus on operational multiplication of a few elite clones, and the development of clonal planting materials that can be distributed to smallholders locally and through the DAFO nurseries.
- Propagation of teak by grafting has successfully propagated 100 selected trees that are now established in a clone bank and clonal seed orchard. Expansion of the number selected and grafted trees to a total of 200 is recommended. Selection should focus on other regions to expand the potential genetic base of trees that have been selected and preserved through grafting.
- Grafted clone banks and orchard will require careful maintenance to ensure that shoots for the root stocks do not suppress or replace the grafts. Data (e.g. stem straightness) collected on the performance of grafted clones can be used to reselect most promising clones for mass propagation via tissue culture and cuttings.
- Grafted trees should be maintained as hedges at both NAFReC and ARC to provide source of plant material for propagation by tissue culture and cuttings.

- Development of extension and training materials should be priority activity for the first year of the new project. A starting point will be the revision and translation of the Indonesian manual for distribution in Laos.
- Seek opportunities to involve DAFO of northern provinces in the establishment of community groups as part of the new project, and adopt focus of working with communities rather than individual farmers in the new project.
- Seek additional opportunities for redevelopment or enhancement of existing facilities to improve capacity to undertake research in Laos.

10 References

10.1 References cited in report

O. Monteuuis and D. Goh (1999). About the use of teak clones. BOIS ET FORÊTS DES TROPIQUES, 1999, N° 261 (3), downloaded from http://bft.cirad.fr/cd/BFT_261_28-38.pdf, August 23 2013.

10.2 List of publications produced by project

None

11 Appendixes

11.1 Appendix 1:

Teak trees selected and grafted in 2013. Summary of grafting success by location where each tree was selected.

Site No.	Location	Tree Code	Grafts and Buds	Mortality	Survival	%
1	Nam Ou	1-1	30	7	23	77
		1-2	30	15	15	50
		1-3	30	8	22	73
		1-4	30	1	29	97
		1-5	30	11	19	63
		1-6	30	10	20	67
		1-7	30	10	20	67
		1-8	30	15	15	50
		1-9	30	2	28	93
		1-10	30	3	27	90
		1-11	30	11	19	63
		1-12	30	8	22	73
		1-13	30	8	22	73
		1-14	30	11	19	63
		1-15	30	5	25	83
		Average		**8**	**22**	**72**
2	Namkhan-upper	2-1	30	7	23	77
		2-2	30	8	22	73
		2-3	30	6	24	80
		2-4	30	6	24	80
		2-5	30	10	20	67
		2-6	30	3	27	90
		2-7	30	5	25	83
		2-8	30	2	28	93
		2-9	30	6	24	80
		2-10	30	2	28	93
		2-11	30	5	25	83
		2-12	30	10	20	67
		2-13	30	7	23	77
		2-14	30	12	18	60
		2-15	30	4	26	87
		Average		**6**	**24**	**79**

3	Namkhan-lower	3-1	30	4	26	87
		3-2	30	5	25	83
		3-3	30	7	23	77
		3-4	30	3	27	90
		3-5	30	10	20	67
		3-6	30	5	25	83
		3-7	30	5	25	83
		3-8	30	1	29	97
		3-9	30	1	29	97
		3-10	30	4	26	87
		3-11	30	3	27	90
		3-12	30	5	25	83
		3-13	30	9	21	70
		3-14	30	5	25	83
		3-15	30	8	22	73
		Average		**5**	**25**	**83**
4	NamSieang	4-1	30	15	15	50
		4-2	30	8	22	73
		4-3	30	9	21	70
		4-4	30	5	25	83
		4-5	30	12	18	60
		4-6	30	12	18	60
		4-7	30	5	25	83
		4-8	30	4	26	87
		4-9	30	6	24	80
		4-10	30	3	27	90
		4-11	30	8	22	73
		4-12	30	8	22	73
		4-13	30	1	29	97
		4-14	30	2	28	93
		4-15	30	2	28	93
		Average		**7**	**23**	**78**
5	Namkong	5-1	30	3	27	90
		5-2	30	5	25	83
		5-3	30	4	26	87
		5-4	30	10	20	67
		5-5	30	3	27	90
		5-6	30	6	24	80
		5-7	30	9	21	70
		5-8	30	5	25	83
		5-9	30	11	19	63
		5-10	30	9	21	70

		5-11	30	7	23	77
		5-12	30	13	17	57
		5-13	30	4	26	87
		5-14	30	14	16	53
		5-15	30	10	20	67
		Average		**8**	**22**	**75**
6	Nan District	6-1	30	5	25	83
		6-2	30	9	21	70
		6-3	30	5	25	83
		6-4	30	14	16	53
		6-5	30	5	25	83
		6-6	30	12	18	60
		6-7	30	12	18	60
		6-8	30	5	25	83
		6-9	30	7	23	77
		6-10	30	6	24	80
		6-11	30	13	17	57
		6-12	30	9	21	70
		6-13	30	15	15	50
		6-14	30	13	17	57
		6-15	30	15	15	50
		Average		**10**	**20**	**68**
7	DANIDA	7-1	30	10	20	67
		7-2	30	5	25	83
		7-3	30	5	25	83
		7-4	30	4	26	87
		7-5	30	9	21	70
		7-6	30	5	25	83
		7-7	30	4	26	87
		7-8	30	7	23	77
	B. EAN	1	30	1	29	97
		2	30	3	27	90
		Average		**5**	**25**	**82**