Centre for Forest Biotechnology
and Tree Improvement
Yogyakarta, Indonesia

THE UNIVERSITY of ADELAIDE

Completion Report

TFL-PD 037/13 Rev.2 (M)

Implementing a DNA timber tracking system in Indonesia

Executive Summary

Illegal logging and associated trade are the cause of many economic and ecological problems both in timber producer and timber consumer countries. The key problem that was to be addressed by this project is weak capacity in forest law enforcement. This was a two year project on species identification and timber tracking system using DNA methods for important Indonesian timber tree species of the family Dipterocarpaceae, which includes the red, yellow and white meranti groups, bangkirai and balau. Partners the University of Adelaide (Australia) and the Centre for Forest Biotechnology and Tree Improvement in the Forest Research and Development Agency (Indonesia) worked together to deliver the project, alongside industry collaborators Double Helix Tracking Technologies (Indonesia & Singapore).

The Development Objective for the Project was strengthened forest law compliance and governance through improved national policy and legal frameworks, strengthened enforcement and other institutions, improved data and knowledge, strengthened partnerships and improved cooperation among the private sector, civil society.

The Specific Objective for the Project was development and Implementation of species identification and timber tracking systems using DNA fingerprints for important commercial species in Indonesia.

These objectives were to be realized through the following outputs:

1. Generation of DNA barcodes for 50 Dipterocarpaceae species by the end of the project
2. Provision of training and information sharing to Indonesian timber stakeholders including government, industry and certification bodies for timber species identification and control of origin of Indonesian timber, by the end of the project
3. Development of genetic markers for control of chain of custody of one Indonesian Dipterocarpaceae timber species by the end of the project
4. Project coordination

The project was able to deliver against the core objectives, in that technological approaches for timber tracking systems using DNA fingerprints were developed and implemented in demonstration cases for important commercial species in Indonesia. However, the resolution and power of these DNA approaches could be improved through broader screening of the reference samples, and could be further validated through blind sample testing programs. Similarly, implementation of these approaches could be more broadly and systematically adopted in Indonesian timber supply chains, beyond the demonstration cases achieved through this project.

The most critical differences between planned and actual Project implementation were the result of the ITTO financial impairment. The Project was put on hold and funds were delayed and eventually reduced. During this time staff contracts had to be honoured according to Australian law. This put the project in significant deficit and meant that the planned activities had to be modified and scaled back. There was little that could have been done to anticipate or avoid this difficulty.

The future sustainability of the project is currently secured through the appointment of a doctoral candidate in Australia with full scholarship from the Australian government, who will now work to further develop and apply the results of the Project. An additional doctoral candidate from Indonesia is also in the process of applying for a scholarship. CFBTI in FORDA, as part of the Indonesian Government, are well placed to promote and facilitate the continuation of the Project aims.

A significant learning from the project was not to pre-empt funding, even when contracts are in place. The Project was running in deficit for most of its life due to this. In hindsight no funds should have been expended until they had cleared in the EA's accounts. Further, the administrative burden of the project amendments and associated requirements was not sufficiently accounted for in the budgeting.

As it stands, expansive sampling resources from the Dipterocarpaceae in Kalimantan were collected, DNA barcoding resources were developed for 75 species and DNA profiling resources for one species.

Two workshops were held to disseminate project information and engage stakeholders in design and implementation. Three INTERPOL training workshops were attended and a study visit completed by an Indonesian researcher to Australian laboratories. DNA barcoding was implemented in exemplar meranti supply chains to support SVLK certification and improve access to international markets.

Looking towards future projects and the continuation of this work, the recommendations are:

1. Multispecies ID – Dipterocarpaceae
   - Analyse data from a genome screens for a subset of samples from an extensive collection of Dipterocarpaceae from Kalimantan. Identify loci that can distinguish species and then undertake the following:
   - Develop a phylogeny based on these data
   - Develop/apply a method to screen these loci in the remainder of samples, potentially NGS amplicon sequencing, MassArray genotyping, SNaPshot assay, or perhaps a hybrid capture approach.
   - Test the identification capacity of the markers using blind test samples
   - Optimise the test for use on timber extracted DNA in Indonesian labs (SNaPshot or some kind of restriction length polymorphism analysis on key SNPs).
   - Demonstrate the applicability of the test in real life samples from trade
2. Single species ID and species comparisons – Shorea laevis (Bangkirai), Shorea parvifolia (Light red meranti)
   Using existing collections undertake the following:
   - Compare the genetic diversity and differentiation within S. laevis and S. parvifolia.
   - Determine whether patterns are similar for both species and the influence of life history traits and/or demography. Identify whether existing SNP markers developed from S. laevis are variable in other species and develop additional markers if required.
   - Determine whether genetic clustering can be used to accurately assign provenance to unknown samples for timber extracted DNA in Indonesian laboratories. Potentially collect more samples from across the region to include in the analysis.
   - Apply these techniques in partner laboratories overseas in an applied setting.
3. Genome annotation – Shorea laevis.
   - Work on the annotation of the draft genome for S. laevis and use the results to support the above project components.
4. Capacity building and extension
   - Train and develop capability/equipment in Indonesian lab
   - Disseminate to government and industry – hold demonstration workshops with key stakeholders

It is also noted that all future collaborative projects must now obtain Indonesian Ministry of Finance sign off. This will likely lengthen the approval process further and should be accounted for in time and resources when planning future projects.

Context

1.1.1 Geographic location

Indonesia is an archipelago in South East Asia comprising approximately 17,500 islands, with a total land area of 1,904,569 km2, making it the fifteenth largest country in the world by land area: Latitude 5.00° S & Longitude 120.00° W. It has 34 provinces with over 267 million people (1), and is the world's fourth most populous country, expected to grow by a further 50 million people in the next 20 years. Indonesia has long been in a strategic location due to its intersection with major trading routes of the Indian Ocean to Pacific Ocean.

The study took place in two major geographical areas, the laboratory works were carried out at the Laboratory of Molecular Genetics of the Centre for Forest Biotechnology and Tree Improvement in

Yogyakarta. Genetic materials for the study were be collected from Kalimantan where the species occurs naturally. The project team collected samples from across Kalimantan to target all species.

1.1.2 Social, cultural, economic and environmental aspects

1.1.2.1 Indonesia: one of the most mega-diverse countries in the world

The rainforests of Indonesia have some of the highest levels of biological diversity in the world. Indonesia contains the world's third largest area of rainforest after the Amazon and Africa's Congo Basin. Whilst Indonesia is 1 percent of the Earth's land area, its rainforests contain 10 percent of the world's known plant species, 12 percent of mammal species and 17 percent of all known bird species. And there is still much to be discovered. The Indonesian Ministry of the Environment estimates that more than half of Indonesia's species are still unrecorded.

The rapid loss of Indonesia's biologically wealthy rainforests is a major risk to the survival of many Indonesian species. So while Indonesia has more species of mammal than any other nation, 515 species, it also has the highest number of threatened mammals at 135 species. The loss of habitats and potential loss of species causes economic as well as environmental damage, with Indonesian biodiversity responsible for over 11% of its GDP (2).

1.1.2.2 Impacts of illegal forestry on biodiversity in Indonesia

Indonesia's forests are being lost at significant rates, between 1990 and 2005, approximately 108,110 square miles of Indonesian forest disappeared, 77% of which were virgin forest (see Figure 1).

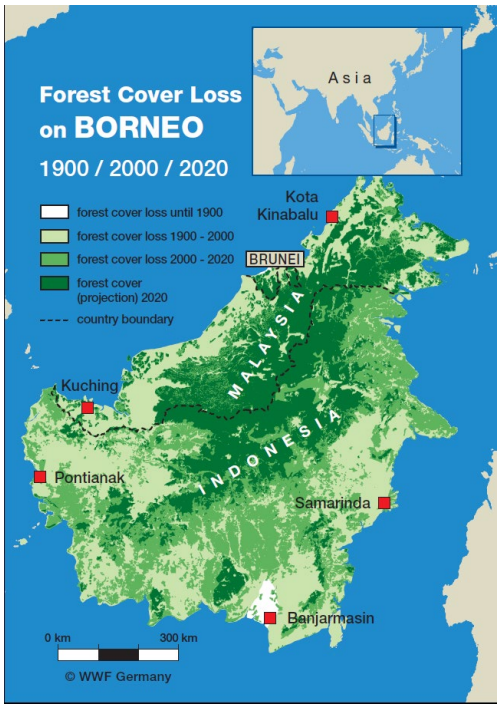
Illegal logging is a major contributor to the loss of Indonesia's forests. A 2007 United Nations Environment Program report estimated that 73-88% of timber logged in Indonesia is illegally sourced. More recent estimates place the figure at a lower rate of 40-55%, which while still troubling, represents a major achievement by an Indonesian government who has shown a commitment to reduce the levels of illegal timber harvesting. The loss of revenue to the Indonesian government from illegal logging is an estimated $2 billion per year due to corruption, uncollected taxes, unacknowledged subsidies, and general poor management of resources.

Increased demand for forests products has brought some financial benefits for poor people living near to forests. But there is also evidence to show that usually, poor communities who are completely dependent on forests lose out to powerful interests, logging companies and migrant workers who reap most of the benefits.

Globally, nearly 500 million people, 200 million of whom are indigenous peoples, depend on forests for their livelihoods (3). Initial processing of wood often occurs in remote and sparsely populated areas with limited job opportunities, social support systems, access to education, and infrastructure. These remote areas are sometimes beyond the control of government authorities. This provides significant opportunities for illegal traders to avoid adherence to local laws relating to fair pay, employment benefits, job training, health and safety, and sharing of benefits with local communities.

In Indonesia, land tenure can be customary or statutory: the former is defined and adhered to by local communities land ownership and management as well as the right to access and use resources. Both customary and statutory land tenure can be ignored by illegal traders. This can lead to violent clashes which have threatened livelihoods and human rights. Even in cases where land tenure is recognized, there can be distributional inequities regarding gender and ethnicity within the community.

Figure 1: Forest cover loss on Borneo



1.1.2.3 Indonesia is the largest producer and consumer of tropical timber

Indonesia, is the largest ITTO producer country (Figure 2), producing about 34 million m3 of sawn and veneer logs a year since 2007 as a result of rising GDP and growing domestic demand from the construction industry. Figure 3 shows tropical log consumption for 2009-2011, which was very similar to production trends in the top four countries. Indonesia is also the world's largest consumer of tropical logs.

The majority of timber exported from the region (51.6% of annual traded value of US$ 208 M- trade figures for Malaysia, 2009, where trade names are accurately recorded and the most similar comparable forest composition to Indonesia, Table 1) comes from the meranti group, particularly the red meranti group.

Indonesia's natural forests face pressure from conversion to agriculture (particularly oil palm plantations) and forest plantations (for the pulp and paper industries), as well as from rising domestic demand for wood products from the growing housing construction sector. Indonesia's industrial round wood production has become increasingly constrained, with the wood processing sector experiencing significant overcapacity and continuing reports of relatively high rates of illegal round wood consumption.

However, some progress in combating illegal logging has been made at the national level. A two-year moratorium of new forest-clearing concessions was announced in 2010 under the climate-change partnership between the Government of Indonesia and the Government of Norway aimed at reducing GHG emissions from Indonesian forests. A compulsory certification scheme for concession holders also imposes a certain degree of oversight on forest operations (4). Indonesia has made a commitment to improve the quality of their industry data. Indonesia is also a signatory to the FLEGT Voluntary Partnership Agreement (VPA) process.

Figure 2: Major tropical wood producers

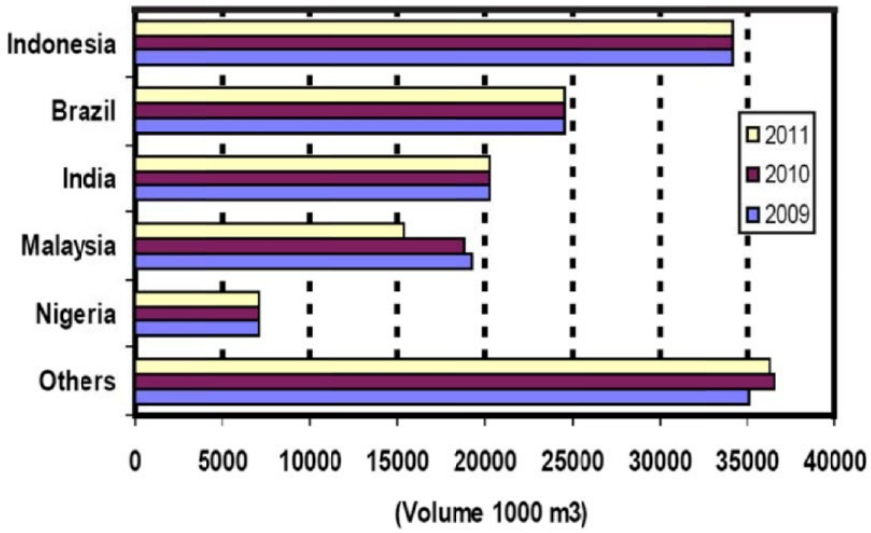


Figure 3: Major tropical wood consumers

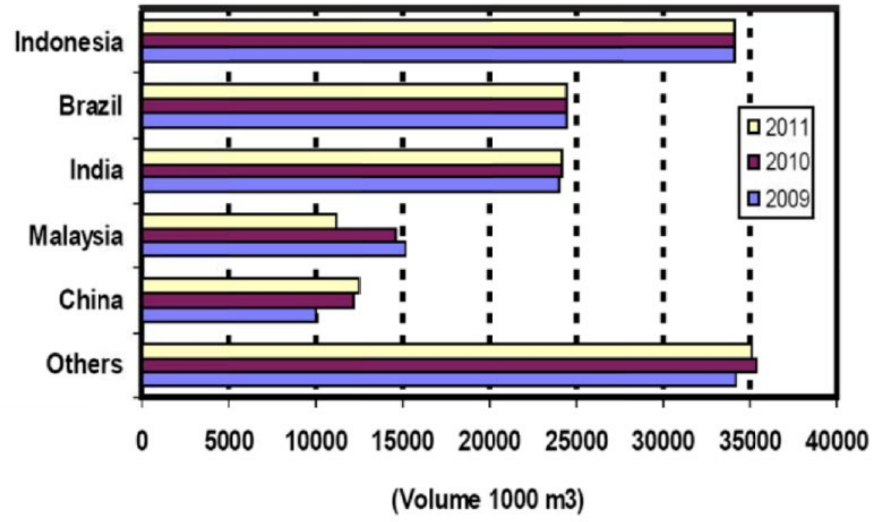


Table 1: Trade and species name and value of important SE Asian meranti timber species

Timber trade name	**Species**	**Trade value (ITTO trade data US$ Million)**
Red meranti	*Shorea amplexicaulis, Shorea splendida, Shorea stenoptera*	71
Dark/light red meranti	*Shorea acuminate, Shorea beccariana, Shorea hemsleyana, Shorea platycarpa, Shorea palembanica, Shorea macrantha*	-
Light red meranti	*Shorea parvifolia ssp. parvifolia, Shorea parvifolia ssp. velutinata, Shorea ovalis ssp. sarawakensis, Shorea ovalis ssp. sericea, Shorea almon, Shorea dasyphylla, Shorea lepidota, Shorea leprosula,Shorea quadrinervis, Shorea rubra, Shorea scrabrida, Shorea smithiana, Shorea teysmanniana*	34
Dark red meranti	*Shorea platyclados, Shorea pauciflora, Shorea ovate, Shorea flaviflora, Shorea curtisii, Shorea coriacea, Shorea argentifolia, Shorea singkawang, Shorea slootenii*	1
Yellow meranti	*Shorea faguetiana, Shorea acuminatissima, Shorea balanocarpoides, Shorea gibbosa, Shorea longisperma, Shorea maxima, Shorea multiflora, Shorea richetia, Shorea xanthophylla*	-

White meranti	*Shorea gratissima, Shorea agami, Shorea assamica, Shorea bracteolate, Shorea henryana, Shorea ochracea, Shorea resinosa, Shorea roxburghii*	-
Other meranti	*Shorea pubistyla, Shorea rugosa, Shorea uliginosa*	2

1.1.2.4 Indonesian economy

Growth in GDP for Indonesia over the past decade has averaged 5.5%, making it one of the strongest emerging economies. The Indonesian economy is the world's sixteenth largest by nominal GDP ($928 billion) and fifteenth largest by purchasing power parity (6). The GNI per inhabitant is $3,495, placing it 109th in the world also making it one of the poorest rapidly developing economies.

The people of Indonesia are highly dependent on the agricultural sector for their livelihoods. Half of Indonesia's people live in rural areas and half of all Indonesian households are primarily dependent upon agriculture – the cultivation of rice and other foods, estate crops such (such as rubber, coconut, palm oil and coffee), livestock and poultry, and fishing. Only 37% of the work-force are estimated to be employees with the remainder self-employed and unpaid. 12.5% of people are classified as living in poverty (1) and two-thirds are classified as undernourished.

1.1.2.5 Contribution of forestry to Indonesian economy

Forests cover 94 million ha, or 52% of the total area of the country. The forestry sector has moved from localized selective felling to large-scale plantation development. The forest-based manufacturing industry has diversified from small manufactures to large-scale plywood production and most recently pulp and paper production.

- Combined, the sectors contribute approximately US$21 billion to Indonesia's GDP, or roughly 3.5 per cent of the national economy;
- Wood products and pulp and paper manufacturing represents around 8.3 per cent of manufacturing value-added;
- The sector employs a combined total of 3.76 million people; around 4 per cent of the working population and roughly 1.5 per cent of the total population;
- If employment multipliers are taken into account, this figure is likely to be closer to or exceed 4 million people;
- If dependents are taken into account, this equates to more than 15 million people dependent upon the sector;

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Forestry (harvesting and silviculture) contributes roughly US$ 5.1 billion (approximately 1 percent) to Indonesia's GDP. The contribution of forestry harvesting to employment is particularly significant. While estimates of employment within the formal forestry sector are around 241,000 according to recent estimates, informal sector employment is much higher. Plantation forestry alone is responsible for approximately 713,000 permanent jobs and approximately 450,000 short-term jobs annually during plantation establishment.

Wood and wood manufacturing contributed US$ 9 billion (around 1.4 per cent) to Indonesia's GDP in 2009. Its share of manufacturing value added was around 2.3 per cent in the same year. Pulp and paper manufacturing and its associated industrial forest plantations combined directly employ around 1.51 million people and contribute around 1.8 per cent of GDP. The pulp and paper industry contribute approximately 1.2 per cent of GDP and approximately 6 per cent of manufacturing value-added. Wood

products and pulp and paper represent 6 per cent of total exports in 2010 and around 9 per cent of non-mineral exports.

1.1.3 Relevant national and regional policies and programs

The project is well aligned with Australia's objectives regarding illegal logging. It supports Australia's illegal logging policy by providing capacity building for Indonesia to implement DNA tracking to complement existing timber legality verification systems. The project provides a mechanism to strengthen the ability to trade in legally sourced and sustainable timber, thus indirectly assisting timber traders and importers to respond to the provisions of Australia's Illegal Logging Prohibition Act.

Combating illegal logging remains Indonesia's top priority in the national forestry development strategy. Recognizing the economic, environment and social impacts of illegal logging to the country, the Ministry of Forestry has intensified law enforcement. In addition, regulation on verification on the legality of timber has also been introduced.

Central to most efforts to tackle illegal logging and associated trade is the need to distinguish between illegal and legal timber at different stages of the supply chain, both to aid enforcement and cut off markets for stolen wood. Systems and technologies that can help achieve this goal are central to successful implementation of both voluntary company-based solutions and mandatory government controls.

DNA technology can be used to trace the origin of timber to clarify a potential illegal origin. The Ministry of Forestry has welcomed the idea to adopt advance technology such as DNA methods to ensure the legality of all timber exported from and marketed in Indonesia. In addition to the existing verification of legal documents, the use of DNA markers (which cannot be tampered with) will further strengthen the robustness of the chain of custody of Indonesia's timber.

The project directly supports the verification of legally sourced timber products from Indonesian sources that are now required by Australian legislation, the European Union's FLEGT Action Plan, and the US Lacey Act.

While the EU FLEGT Action Plan provides measures to support developing countries to achieve improved forest governance, it also provides for Voluntary Partnership Agreements between timber-producing developing countries and the EU. The latter requires partner countries to implement a timber licensing scheme and EU border control agencies to allow imports from these countries only if they are accompanied by FLEGT licenses. According to the EU, the tracking systems should be reliable, cost efficient and forgery proof, something that can only be achieved if physical controls at critical points are intensified. This is where robust methods to verify the origin of timber such as DNA of timber would complement existing methods and help demonstrate the exact origin of wood. In Indonesia, the legality system implemented as part of the EU FLEGT Voluntary Partnership Agreement is the SVLK and is a major initiative of the Ministry of Forestry.

Finally the project helps to improve monitoring and control of CITES listed species. Forest policies are dealing with the monitoring and control of these species and most of them have only had limited success so far. Better traceability methods (such as the ones developed by the current project) are expected to improve the monitoring and identification of CITES species by customs authorities.

Origin and Problem

1.2.1 Origin

Illegal logging contributes to deforestation and by extension climate change, causes loss of biodiversity and undermines the rule of law. Illegal logging takes place when timber is harvested, transported, and bought or sold in violation of national laws. These illegal activities undermine responsible forest management, encourage corruption and tax evasion and reduce the income of people legitimately relying on forest products for their livelihoods.

Responding to the widespread illegal logging in Indonesia's forests, the Indonesian Ministry of Forestry has set out combating illegal logging as one of the top five priorities of the Ministry of Forestry national strategy. In addition to calling on consumer countries to ban the entry of illegal wood from Indonesia, the Ministry of Forestry has also intensified law enforcement to curb illegal logging. In the international forum, the development of specific initiatives targeting the problem of illegal timber, such as the EU Action Plan on Forest Law Enforcement, Governance & Trade (FLEGT), and government procurement policies in consumer countries, are a consequence of this need.

The original proposal for this project was an outcome of a workshop held in Kuala Lumpur, Malaysia between 24-26th April 2012 on 'Identification of Timber Species and Origins', organized by the Global Timber Tracking Network, at which the project partners met and began planning the project. The partners recognized the need to introduce a DNA tracking system for some of the major dipterocarp species of Indonesia. Implementation of such a tracking method would not only help Indonesia to clamp down on illegal logging but equally importantly, would also enhance the efforts to conserve the diminishing resources of these species.

1.2.2 Problem

The key problem addressed within the project is the inefficient tree species identification and control of timber origin in Indonesia. The consequences are that existing forest laws and regulations against illegal logging are not enforced properly. As long as this is the case illegal timber with manipulated documents claiming legality will remain on the market. And because the costs for illegal timber are significantly lower there will also remain a market disadvantage for legally harvested timber. Further analysis of the problem is given in section 2.1.3.

Project Objectives and Implementation Strategy

2.1 Project Rationale

2.1.1 Institutional set-up and organizational issues

It was originally agreed that four partners would work together to implement the project. Two from producer and two from consumer countries. These were:

- The University of Adelaide, Australia (UoA)
- Centre for Forest Biotechnology and Tree Improvement in the Forest Research and Development Agency, Indonesia (CFBTI in FORDA)
- The Institute of Forest Genetics in the Thünen Institute, Germany (TI)
- The World Resources Institute, Indonesia (WRI)

However, at project inception, WRI were unable to participate in the project as planned. Further, as the financial impairment of ITTO caused projects to be placed on hold for an extended period without funds, and there was some lack of clarity over what funding would eventually become available, plans to work with TI were cancelled. Hence, the final project was delivered between UoA and CFBTI in FORDA.

The UoA was the executive agency and coordinator of the project. For over 20 years, the group of Professor Andrew Lowe, Director of Food and Fibre Innovation and Chair of Plant Conservation Biology, has been researching the topic of DNA profiling for timber tracking and DNA barcoding of trees.

CFBTI in FORDA is a key provider of forest research in Indonesia and has a major stake in the development of DNA tracking technologies for chain of custody compliance. As a part of the Ministry of Forestry, CFBTI in FORDA is in an ideal position to influence the policy agenda in Indonesia. The involvement of CFBTI in FORDA and the Ministry of Forestry more generally was at both a strategic level on the Steering Committee, and at an operational level as a key delivery agent for the project. Crucially, CFBTI in FORDA is in the best

position to secure the ongoing sustainability of the outcomes from this project, by acting as the champion and delivery agent of DNA testing inside the Indonesian government.

2.1.2 Stakeholder analysis

Stakeholder group	Characteristics	Problems, needs, interests	Potentials	Involvement in the project
Primary stakeholders				
DG of Management of Forest Utilization	Responsible for the management and utilization of production forest	Recognize the potential but concern over the cost	Provide information of logging areas	Assistance in data and sample gathering
Provincial Forestry Service	Directly involved in utilization of the dipterocarps	Insufficient capacity and capability to control illegal logging	Assistance to access field site	Ground support for sample collection
Forest concessionaires	Derive revenues from timber logging	Face competition from illegally logged timber; concern about practical field application of the system; concern over what will happen to the current timber tracking methods; concern over the cost and who will pay for that	Have good knowledge of timber resources	Primary project beneficiaries, will assist for sampling
Timber trade federations and private companies	Derive revenue from timber and timber products trade	'Wait and see' proof that the system works and to know how it will be linked with current regulations; concern by the cost	Experienced in the wood and wood-based products market	Primary beneficiaries, can supply samples for blind test
FLEGT + CITES control authorities in timber producer and timber consumer countries	Are responsible for the legality control of timber exports and imports	Need reliable tools to control species and origin; may have wrong expectations on the costs; need to know which method is suitable for which control	Can specify the control needs	beneficiaries
Secondary stakeholders				
NGO's and development agencies	Actively involved in the sustainable management of natural resources	Want to develop small verification kits usable directly in the field	Experienced in working with various stakeholders from developing and developed countries	Can help during sampling, training and capacity building; will organize the blind test; can multiply the funding and lead in the extension of the system
Indonesian forest administrations	Make, implement or control forest management plans	Need training for sampling and implementation of the system	Experienced in existing timber tracking systems; knowledge of Indonesian forests; can mobilize staff for assistance	Can assist for sampling; can provide authorization and assistance to sample in protected forests and concessions
Indonesian government	Make and implement forest laws	Needs to have non-falsifiable control methods guaranteeing the origin of wood and wood products	Desire to stop illegal logging; have the authority and influence to implement new timber tracking system	Primary project beneficiaries; Can incorporate the system into forest laws

Certification organisations	Attest the origin of wood raw material and its status and/or qualifications; have systems designed to measure forest management practices against standards and to demonstrate compliance with those standards	Support implementation of robust timber legality system (SVLK); low percentage of Indonesian forest certified; specific ecological, social and economic performance indicators can be manipulated along the chain of custody; needs to have indicators that cannot be manipulated	Experienced in working with stakeholders the timber industry	Primary project beneficiary; can use DNA fingerprinting techniques to increase certification standards
CFBTI in FORDA	Responsible for R&D to support policy development	Improved research outputs and outcomes to support MoF policy	Policy support to conduct advance research	Guidance in project implementation
Tertiary stakeholders				
Indonesian regional organizations	Primary authority for decision-making and coordination of sub-regional actions and initiatives pertaining to the conservation and sustainable management of forests	Project cover some of their strategic priorities: knowledge of the resource, management of ecosystems; sustainable exploitation of forest resources, monitoring, strengthening of capacities, training; research development	Authority and influence in the region	Desire to be member of the steering committee and to coordinate training and education activities
Western countries governments	Make and implement forest laws	Have laws and regulations prohibiting the placing on the market of illegally sourced timber; Since March 2013, the EU-timber-trade-regulation obliges operators to prove the origin of wood and wood products imported to the internal EU-market; needs non-falsifiable methods to control the origin of wood and wood products	Great desire to stop illegal logging; have already appropriate laws and the means to enforce them	Supporting the project financially; will apply the system to track timber
International organizations: (Bioversity International)	Carry out global research to seek solutions for sustainable agriculture, nutrition and conservation; host the newly established international facility "Identification of Timber Species and Origins"	Want to use the international database as a tool to promote the up-scaling of DNA fingerprinting techniques; needs supports from all institutions working in the field	Competence in coordinating research, setting standards and establishing network	Can host the project reference database
Western countries universities and research institutes	Have education and research missions	Lack means to finance new timber tracking research	Competence in research; studies and training	Will collaborate in implementing project activities; might look for additional funding

Commercial partners	Provide service on origin checking for public authorities, NGOs and forest companies	Needs to get better access to the market	Important pathway of technology transfer and durable application of the project's results	Will do part of the genetic screening for the reference data bases and will participate in blind tests
Indonesian universities and research institutes	Have education, training and research-development mandates	Lack: means to finance research; DNA fingerprints laboratory in many institutes; Needs: training of trainers, education of young scientists; Interests: host reference laboratory or have small equipment necessary to perform timber tracking works	Competence in research; experienced in teaching and training in Indonesia	Will assist in sampling; desire to organize training and education activities; desire to include know-how and knowledge generated by the project into curricula of existing degree and non-degree programmes

2.1.3 Problem analysis

As stated in section 1.2.2, the key problem addressed within the project is the inefficient tree species identification and control of timber origin in Indonesia. The consequences are that existing forest laws and regulations against illegal logging are not enforced properly. As long as this is the case illegal timber with manipulated documents claiming legality will remain on the market. And because the costs for illegal timber are significantly lower there will also remain a market disadvantage for legally harvested timber.

What are the causes of the missing application of tamper proof methods? For more than 100 years, wood anatomical approaches have been used for the identification of tree species. However, for many important Indonesian timber species, particularly from the family Dipterocarpaceae (e.g. the meranti group) wood anatomy hasn't been successful at discrimination down to species level. The modern alternative is DNA barcoding. This approach searches for genetic differences among species and develops gene markers that screen these differences. But for many species worldwide, we still need to develop the DNA barcodes. Genetic profiling is also a very reliable approach to control the origin of timber. Unfortunately, for the important Indonesian timber species a reference database with the spatial distribution of DNA profiles across the range of a species has not yet been developed.

There are two main reasons for the lack of application of genetic approaches in Indonesia: a) there are no reference labs with trained persons and sufficient equipment, and (b) lack of initiatives of various stakeholders group (private sector, government, NGOs, development agencies etc.) in this area, caused by a low level of knowledge of the potential of the new genetic tools.

2.2 Development Objective

The Development Objective for the Project is: Strengthened forest law compliance and governance through improved national policy and legal frameworks, strengthened enforcement and other institutions, improved data and knowledge, strengthened partnerships and improved cooperation among the private sector, civil society.

2.3 Specific Objective

The Specific Objective for the Project is: Development and Implementation of species identification and timber tracking systems using DNA fingerprints for important commercial species in Indonesia.

2.4 Project Implementation Strategy

2.4.1 Outputs and activities

2.4.1.1 Original Outputs

At the original inception of the Project, the following four outputs were defined:

1. 50 tree species from the meranti group have been identified by DNA barcoding
2. Genetic reference data to control the country of origin for two important timber species have been created
3. Indonesian personal trained for timber species identification and control of origin
4. Demonstration of control of chain of custody with one meranti species and stakeholders have been involved

2.4.1.2 Adjusted Outputs

Through the course of implementation, the outputs were adjusted as follows (through discussion with and agreement from ITTO)

1. Generation of DNA barcodes for 50 Dipterocarpaceae species by the end of the project
   Justification: the target species were expanded from just meranti (genus Shorea) to include all members of the Dipterocarpaceae family. This expansion was in recognition of the fact that many Dipterocarpaceae species are indistinguishable and often traded as meranti even when not in the Shorea genus.
2. Provision of training and information sharing to Indonesian timber stakeholders including government, industry and certification bodies for timber species identification and control of origin of Indonesian timber, by the end of the project
   Justification: Broadening of scope for previous output 3 to incorporate training and workshops.
3. Development of genetic markers for control of chain of custody of one Indonesian Dipterocarpaceae timber species by the end of the project
   Justification: Combining of original outputs 2 and 4, reduction to one species rather than two, due to financial impairment and associated delays and uncertainties. Additionally, as originally identified in assumptions and risks (section 2.4.3.1), output 2 was contingent upon additional funding being secured from the Australian Research Council (ARC). As this funding was not forthcoming, this output required amendment.
4. Project coordination
   Justification: output to capture coordination activities.

2.4.1.3 Original Activities

2.4.1.3.1 For Output 1:

1. CFBTI in FORDA to sample wood probes and cambium or leaves from 100 individual trees
2. CFBTI in FORDA and University of Adelaide to develop DNA barcodes for 50 tree species
3. CFBTI in FORDA undertake blind testing of 50 samples from unknown origin based on barcoding analysis

2.4.1.3.2 For Output 2:

1. CFBTI in FORDA to sample cambium or leaves from up to 800 individual trees belonging to 2 species (up to 40 locations and 10 samples per location for genetics)
2. University of Adelaide to optimise DNA extraction protocols for wood
3. University of Adelaide to develop genetic markers (chloroplast and nuclear microsatellites, SNPs) for red meranti

4. University of Adelaide to develop genetic markers (chloroplast and nuclear microsatellites, SNPs) for light red meranti
5. CFBTI in FORDA and University of Adelaide to undertake DNA fingerprinting of up to 400 red meranti trees
6. CFBTI in FORDA and University of Adelaide to undertake DNA fingerprinting of up to 400 light red meranti trees
7. CFBTI in FORDA undertake blind testing of 50 samples from unknown origin belonging to 2 species based on DNA fingerprinting

2.4.1.3.3 For Output 3

1. Training in Australia and Indonesia of Indonesian scientists in marker development, barcoding and DNA fingerprinting
2. In-house training by University of Adelaide scientist in Indonesian lab
3. Development of communication strategy by CFBTI in FORDA and University of Adelaide to ensure that policy makers and general public are well informed
4. CFBTI in FORDA and University of Adelaide to organize national workshop on timber tracking using DNA markers
5. World Resources Institute works with CFBTI in FORDA to identify the required conditions in Indonesia for the implementation of DNA markers in timber tracking
6. CFBTI in FORDA and World Resources Institute to evaluate existing log tracking systems
7. CFBTI in FORDA works with stakeholders to identify suitable conditions for implementation of log tracking using DNA markers

2.4.1.3.4 For Output 4

1. CFBTI in FORDA to sample cambium or leaves and wood probes of 100 meranti trees
2. CFBTI in FORDA and University of Adelaide to develop DNA fingerprinting for 100 meranti trees
3. CFBTI in FORDA and University of Adelaide to train local staff from enforcement and scientific testing agencies in Indonesia in the use of genetic markers for enforcement of Indonesian timber laws
4. CFBTI in FORDA to organise meetings with stakeholders to make them aware of the power and application of genetic markers for enforcement of Indonesian timber laws

2.4.1.4 Adjusted Activities

Through the course of implementation, the activities were adjusted as follows (through discussion with and agreement from ITTO). Activities were adjusted to align with the new outputs and in consideration of the impacts to the Project of the ITTO financial impairment and associated delays and uncertainties.

2.4.1.4.1 For Output 1:

1. CFBTI in FORDA to sample wood probes and cambium or leaves from 1000 individual trees
2. University of Adelaide to develop sampling app
3. University of Adelaide and CFBTI in FORDA to develop markers for 50 tree species
4. University of Adelaide to optimise DNA extraction protocols for wood

2.4.1.4.2 For Output 2:

1. Training in Australia and Indonesia of Indonesian scientists in marker development, barcoding and DNA fingerprinting
2. Development of communication strategy by CFBTI in FORDA and University of Adelaide to ensure that policy makers and general public are well informed
3. CFBTI in FORDA and University of Adelaide to organize national workshop on timber tracking using DNA markers
4. CFBTI in FORDA and University of Adelaide work with stakeholders to identify the required conditions in Indonesia for the implementation of DNA markers in timber tracking
5. CFBTI in FORDA to evaluate existing log tracking systems

2.4.1.4.3 For Output 3

1. CFBTI in FORDA to sample cambium or leaves and wood probes of 100 bankirai trees
2. CFBTI in FORDA and University of Adelaide to develop DNA fingerprinting markers for bangkirai trees
3. CFBTI in FORDA and University of Adelaide to train local staff from enforcement and scientific testing agencies in Indonesia in the use of genetic markers for enforcement of Indonesian timber laws
4. CFBTI in FORDA to organise meetings with stakeholders to engage them in project design and relevance and make them aware of the power and application of genetic markers for enforcement of Indonesian timber laws

2.4.1.4.4 For Output 4

1. University of Adelaide to provide executive agency coordination
2. CFBTI in FORDA and University of Adelaide to coordinate a kick-off meeting
3. Steering committee formed by CFBTI in FORDA and the University of Adelaide
4. Steering committee and partners meetings schedule developed by CFBTI in FORDA and the University of Adelaide

2.4.2 Implementation approaches and methods

2.4.2.1 Original approaches and methods (taken directly from original Project Document)

The approach of implementing the laboratory work of this project will be divided into a series of activities. Collection of genetic materials for genetic analysis will be one of the top priorities. At the same time techniques for DNA extraction from woody materials has to be developed. The laboratory work essentially consists of DNA extraction and purification, Polymerase Chain Reaction (PCR) reaction, electrophoresis and data scoring, analysis and interpretation. DNA markers to be examined for the chloroplast DNA are SNP and microsatellite/SSR. The steps are summarized in the following:

Development of DNA extraction protocols: The first challenge for using genetic markers in timber identification is to successfully isolate DNA from dry wood. For most genetic study, generally DNA is isolated from leaves or seeds of a species. However, since wood is the target of examination, the existing method for DNA extraction that is common for leaf material cannot be applied. Wood contains compounds that inhibit PCR technique. Furthermore, the timber products that reach the market may consist of only heartwood, which is not a good source of DNA since it contains dead cells. However, extraction of DNA from wood has been successful and reported.

Milestones:

- Preliminary works on DNA extraction has been carried out and showed promising results.
- Testing a range of different wood samples to test the robustness of the protocols.

Development of chloroplast DNA primers: Chloroplast DNA is maternally inherited and dispersed through both pollen and seeds. The consequence of this is the chloroplast DNA variation is often highly geographically structured, suitable to identify geographic origin. The DNA is found in many copies and thus the probability of PCR amplification success is likely to be high. Primers will be developed as universal primers for non-coding region of chloroplast DNA via the Polymerase Chain Reaction (PCR).

Milestones:

- Indonesian researcher has experience in developing primers for chloroplast DNA of other species. The approach to primers development is universal.
- Developing SNP and SSR primers for chloroplast DNA
- Construction of genetic database: Genetic database would be the baseline for identification of timber origin. DNA profile of wood sample would be interrogated against the database. The first level of verification would be to check the geographic origin of the wood sample.
- Collection of sample materials from the whole range of populations and successful isolation of DNA
- Differentiation of geographic populations using DNA markers developed by the project

2.4.2.2 Adjusted approaches and methods

After revision of the Project Outputs and Activities to align with the new outputs and in consideration of the impacts to the Project of the ITTO financial impairment and associated delays and uncertainties, the approaches and methods were adjusted as follows:

Stakeholder consultation: The project will be implemented collaboratively by the project partners and will include regular consultation with stakeholders through the steering committee process and via a series of workshops that will be held during the life of the project. These workshops will engage local industry, government, certification and scientific organisations and will act as a conduit for information sharing between the project partners and the broader community of stakeholders. A communication strategy will be designed and implemented to ensure that policy makers and the general public are well informed

Milestones:

- Organisation of regular steering committee meetings
- Delivery of preliminary stakeholder workshop to incorporate industry requirements into specific project plans
- Development and implementation of a communication strategy for policy makers and the public
- Delivery of training workshops to inform the broader community of the project outputs, provide training on appropriate utilisation and acquire industry feedback

Reference material collection: Collection of reference materials for genetic analysis is a top priority as all further work relies on this as a basis. The field work will be approached in multiple discreet field sampling trips which are centred on particular areas of interest in the various provinces of Kalimantan. These sites (see figure 2) are chosen based on existing infrastructure (e.g. research stations in national parks etc.). The field teams will be well equipped and experienced, and local knowledge will be utilised through the employment of guides, porters and assistants from the local areas who can advise on logistical matters and provide support. Each field team will include a taxonomist who is familiar with the Dipterocarpaceae and voucher specimens will be collected where possible to facilitate post-hoc taxonomic verification. In order to manage the large amounts of data and associated samples, a field sampling app and associated database will be developed which can ensure the integrity of samples and their associated metadata.

Milestones:

- Collection of leaf, cambium, voucher specimens and wood cores from natural populations of Dipterocarpaceae species across Kalimantan, >5 individuals per species
- Collection of leaf, cambium, voucher specimens and wood cores from natural populations of bangkirai (Shorea laevis) from across Kalimantan, ~30 individuals per population
- Development of field sampling app and database to collect sampling information.

Development of DNA extraction protocols: The first challenge for using genetic markers in timber identification is to successfully isolate DNA from timber. For most genetic studies, DNA is isolated from the leaves or seeds of a species. However, since wood is the target of examination, the existing method for DNA extraction that is common for leaf material cannot be applied. Wood contains compounds that inhibit downstream analyses. Furthermore, the timber products that reach the market may consist of only heartwood, which is not a good source of DNA since it contains dead cells. However, extraction of DNA from wood has been successful and reported. The project will focus on further optimising these approaches to maximise the DNA yield obtained from timber products.

Milestones:

- Preliminary works on DNA extraction have been carried out and show promising results
- Testing a range of different timber samples, to assess the robustness of the protocols

Development of DNA markers: Once DNA extraction from timber has been optimised, suitable DNA markers need to be identified and optimised for the desired species groups. Our approach utilises double

digest restriction associated DNA (ddRAD) sequencing to identify novel barcoding loci in the Dipterocarpaceae and single nucleotide polymorphisms (SNPs) in bangkirai.

Milestones:

- Double Digest Restriction Associated DNA (ddRAD) Sequencing to identify novel barcoding loci in the Dipterocarpaceae and single nucleotide polymorphisms (SNPs) in bangkirai
- Selection of SNPs

Training and capacity building in Indonesia: Throughout the project, researchers from Adelaide will work closely with researchers from Indonesia to facilitate knowledge transfer and training in the latest genetic techniques and their downstream application to timber identification. By the end of the project, CFBTI in FORDA should be able to continue developing the identification tests independently.

Milestones:

- Visit by Australian scientists to Indonesian laboratory to advise on lab set up and protocols
- Visit by Indonesian scientists to Australian laboratory to learn DNA extraction and low-copy number DNA contamination-avoidance work flows
- Delivery of training to train local staff from enforcement and scientific testing agencies in Indonesia in the use of genetic markers for enforcement of Indonesian timber laws

2.4.3 Identified Assumptions and Risks

2.4.3.1 Original assumptions and risks (taken directly from original Project Document)

The sampling of the plant material for the two meranti timber species to develop the reference data bases for origin assignment is labour intensive and complicated work. It needs a good coordination between different teams and we need to get access to remote places. The sampling teams need to be well trained. We will follow a two-step sampling approach with a first genetic screening of 2/3 of all samples followed by a first data analysis and the remaining 1/3 sampling according to the first results and identified high priority sampling regions. The sampling will be coordinated by Anto Rimbawanto from CFBTI in FORDA, who has significant experience with sampling in Indonesia over many years.

The application of DNA markers to assign species and origin of processed timber assumes that the quality of extracted DNA is sufficient. To keep the risk of insufficient DNA quality as low as possible we will (a) put particular emphasis to further develop the DNA extraction protocols, and (b) work with DNA-markers that show genetic variation for short DNA fragments because these DNA markers are less sensitive to degraded DNA.

Assigning the geographic origin of timber assumes that the underlying spatial genetic pattern of DNA-markers in the natural distribution area of the tree species is high strong enough. To be sure on that we will (a) develop a high number of DNA-markers for each of the two species using the new generation DNA sequencing approach and (b) make a combined application of DNA-markers to assign the region of origin.

The forest authorities and logging companies might stay sceptical about the developed reinforcement tools. We will try to involve them as much as possible in the project. Good results of the blind tests should convince them on the power of the enforcement tools.

The total budget of the project includes two satellite projects covering a complementary part of the ITTO work program. For this part proposals have been submitted by the University of Adelaide and the TI to the Australian Research Council (Discovery Project requested additional budget = 656,000 US$). There is a risk that this proposal is not successful. In that case the extra sampling planned for the two target species would not be completed but this will not endanger the planned output from the project.

Key Assumptions

- The local partner CFBTI/FORDA will play a key role in the project delivery and governance and will continue to promote the use of DNA-based compliance within Indonesia
- DNA timber tracking system introduced into countries policies and practices
- Commitments from timber importing countries to use the system
- Strong commitments from timber producing countries governments to participate to the project
- Strong support from partners and stakeholders
- Presence of variation in DNA barcode sequence
- Strong commitments from timber producing countries partners and stakeholders to support sampling
- Presence of DNA sequence variation in the genome of each species showing clear spatial genetic pattern
- Commitment from Indonesian partners to have staff members trained
- Commitment of partners staff members to do the training
- Presence of SNP markers in the genome of each species showing sufficient variation and a fine scale spatial genetic pattern
- Protocols on DNA extraction of processed timber are sufficient developed

2.4.3.2 Adjusted assumptions and risks

In addition to the original assumptions and risks identified in section 2.4.3.1, the following was added to the adjusted Project Document through the implementation process:

Sampling for reference collections assumes that individuals of the desired species can be located and correctly identified. It also assumes that the resulting physical samples and metadata can be accurately collected, documented and curated to ensure that DNA identification tests are not built on an incorrect premise of species ID. The risk of these assumptions not being met can be very high in large projects dealing with diverse suites of species such as those found in the family Dipterocarpaceae. In order to mitigate these risks, an expert taxonomist will accompany field teams and collect herbarium voucher material where possible to allow verification of species identity. A field sampling app will also be developed which facilitates the real time capture of sample metadata in the field and uploads these data to an online database.

Project Performance

3.1 Performance against the Specific Objective

The project performed moderately well against the specific objective (as specified in section 2.3) in that technological approaches for timber tracking systems using DNA fingerprints were developed and implemented in demonstration cases for important commercial species in Indonesia (see Technical Reports)

3.2 Performance against Outputs and related Activities

Performance against the adjusted Outputs (section 2.4.1.2) and adjusted Activities (section 2.4.1.4) is provided.

3.2.1 Performance against Output 1 and related Activities

Output 1. Generation of DNA barcodes for 50 Dipterocarpaceae species by the end of the project

Overall Performance against Output: Good – DNA barcode data generated for >50 Dipterocarpaceae species. See Technical Report on Sample Collection; Technical Report on DNA Extraction Optimisation; Technical Report on DNA Barcoding.

Activity 1. CFBTI in FORDA to sample wood probes and cambium or leaves from 1000 individual trees
Performance against Activity: Excellent - >1000 trees samples. See Technical Report on Sample Collection.

Activity 2. University of Adelaide to develop sampling app
Performance against Activity: Moderate – Sampling App conceptualised, alpha version created and tested in the field on two independent field trips. Further refinement and finalisation remains incomplete. See Technical Report on Sample Collection.

Activity 3. University of Adelaide and CFBTI in FORDA to develop markers for 50 tree species
Performance against Activity: Good – Genetic analysis of >70 species was undertaken and marker loci identified. See Technical Report on DNA Barcoding

Activity 4. University of Adelaide to optimise DNA extraction protocols for wood
Performance against Activity: Excellent – extensive DNA extraction optimisation on timber completed. See Technical Report on DNA Extraction Optimisation.

3.2.2 Performance against Output 2 and related Activities

Output 2. Provision of training and information sharing to Indonesian timber stakeholders including government, industry and certification bodies for timber species identification and control of origin of Indonesian timber, by the end of the project

Overall Performance against Output: Good – through training visits, a workshop and meetings, plus industry implementation of pilot DNA testing, information was shared with Indonesian timber stakeholders on timber species identification and control of origin of Indonesian timber. See Technical Report on Training and Information Sharing.

Activity 1. Training in Australia and Indonesia of Indonesian scientists in marker development, barcoding and DNA fingerprinting

Performance against Activity: Good – Indonesian scientist visited Adelaide for a period of two weeks to train in the Advanced DNA Identification and Forensic Facility Laboratories on DNA extraction from timber, marker application and lab set up to minimise contamination risks. Australian scientists visited Indonesian laboratories for two days for provision of on-site training. Further study visits were planned at project inception but were curtailed due to the ITTO financial impairment impacts. See Technical Report on Training and Information Sharing; Technical Report on Industry Testing.

Activity 2. Development of communication strategy by CFBTI in FORDA and University of Adelaide to ensure that policy makers and general public are well informed

Performance against Activity: Moderately Good – a communication strategy was developed. Implementation of the strategy was limited however due to reduced outputs and delays as a result of the ITTO financial impairment. See Technical Report on Training and Information Sharing.

Activity 3. CFBTI in FORDA and University of Adelaide to organize national workshop on timber tracking using DNA markers

Performance against Activity: Excellent – a well-attended workshop was held 10-11 March 2016 entitled "Implementing a Verification System for Indonesian Timber". See Technical Report on Training and Information Sharing.

Activity 4. CFBTI in FORDA and University of Adelaide work with stakeholders to identify the required conditions in Indonesia for the implementation of DNA markers in timber tracking

Performance against Activity: Good – the second half of the workshop (activity 3 above) was focused on industry perspectives of the potential utility of DNA verification and the conditions required to facilitate implementation. Further, through working directly with industry to apply DNA tests alongside SVLK certification, the appropriate conditions to promote uptake were further explored and understood. See Technical Report on Training and Information Sharing; Technical Report on Industry Testing.

Activity 5. CFBTI in FORDA to evaluate existing log tracking systems

Performance against Activity: Good - FORDA and DoubleHelix have worked closely with the forest management authorities and auditors involved in the implementation of SVLK in Indonesia. Workshops were held and stakeholders from the sector invited to air their views and help refine the implementation of DNA timber tracking to verify SVLK claims. Whilst it was considered that the implementation of DNA checks for national markets would probably not be cost effective, for international markets and high value timber products, it was acknowledged that additional verification would help products secure access to more profitable international markets. In addition, the DNA verification methods developed were used in real-world situations to verify the claims of species of origin for a number of timber shipments exported from Indonesia destined for international markets. These tests worked well on the sampled material, provided support for the source claims made and helped verify the source validity of the product. None of the products verified in this way were stopped from international import. Due to this work, the DNA timber tracking methods developed by the project can be applied in a complementary way alongside the Indonesia timber tracking systems (SVLK) to provide additional verification if external markets/products require it. See Technical Report on Training and Information Sharing; Technical Report on Industry Testing.

3.2.3 Performance against Output 3 and related Activities

Output 3. Development of genetic markers for control of chain of custody of one Indonesian Dipterocarpaceae timber species by the end of the project.

Overall Performance against Output: Good – extensive sampling complete for two species, genome sequencing complete for Shorea laevis, double digest restriction amplified DNA (ddRAD) analysis complete using 24 samples from across the sampled range of the species in Kalimantan. Putative SNP loci identified but no population screening or chain of custody testing completed using the developed markers. DNA barcoding on industry samples demonstrated in Shorea laevis. Extensive engagement with local staff from enforcement and scientific testing agencies in Indonesia and beyond, through partnership with INTERPOL and US Department of Justice. See Technical Report on Sample Collection; Technical Report on DNA profiling; Technical Report on Training and Information Sharing.

Activity 1. CFBTI in FORDA to sample cambium or leaves and wood probes of 100 bankirai trees

Performance against Activity: Excellent – 256 individual Shorea laevis trees were sampled from across Kalimantan. An additional 347 individuals of Shorea parvifolia were sampled. See Technical Report on Sample Collection.

Activity 2. CFBTI in FORDA and University of Adelaide to develop DNA fingerprinting markers for bangkirai trees

Performance against Activity: Moderate – genome sequencing complete for Shorea laevis, double digest restriction amplified DNA (ddRAD) analysis complete using 24 samples from across the sampled range of the species in Kalimantan. Putative SNP loci identified but no population screening or chain of custody testing completed using the developed markers. DNA barcoding on industry samples demonstrated in Shorea laevis. SeeTechnical Report on DNA profiling.

Activity 3. CFBTI in FORDA and University of Adelaide to train local staff from enforcement and scientific testing agencies in Indonesia in the use of genetic markers for enforcement of Indonesian timber laws

Performance against Activity: Excellent – Participation as trainers by Project staff in two Indonesian and one international (PNG) workshop run jointly by INTERPOL and the US Department of Justice aimed at reducing illegal logging, land encroachment and related financial crimes. Project staff presented information on forensic timber identification methodologies and the current Project. See Technical Report on Training and Information Sharing.

Activity 4. CFBTI in FORDA to organise meetings with stakeholders to engage them in project design and relevance and make them aware of the power and application of genetic markers for enforcement of Indonesian timber laws

Performance against Activity: Good – through a series of meetings and workshops, stakeholders from government and industry were invited to learn about the project and help steer its direction, as well as more broadly learn about the potential application of DNA testing to Indonesian timber supply chains. See Technical Report on Training and Information Sharing.

3.2.4 Performance against Output 4 and related Activities

Output 4. Project coordination

Overall Performance against Output: Good – project was coordinated well, however there were significant impacts from the ITTO financial impairment which affected staff contracts and availability. See Technical Report on Training and Information Sharing.

Activity 1. University of Adelaide to provide executive agency coordination
Performance against Activity: Good – despite the ITTO financial impairment, UoA was able to continue to manage and coordinate the project to completion.

Activity 2. CFBTI in FORDA and University of Adelaide to coordinate a kick-off meeting
Performance against Activity: Good – a kick off meeting was held early in the project to establish the strategy for undertaking the project

Activity 3. Steering committee formed by CFBTI in FORDA and the University of Adelaide
Performance against Activity: Good – a steering committee involving representatives from the Indonesian and Australian governments was established to monitor and direct the project

Activity 4. Steering committee and partners' meetings schedule developed by CFBTI in FORDA and the University of Adelaide
Performance against Activity: Good – a schedule was developed, however it had to be pared-down to a minimum accommodate the ITTO financial impairment impacts.

3.3 Performance against schedule: Starting date; Duration

Original project dates. 15th August 2015 – 15th August 2017
Adjusted project dates: 15th August 2015 – 31st October 2018

Performance against schedule: Poor – some early problems with the project management team and administrative hurdles within the EA meant the start date was delayed by many months. Once the project was able to begin, progress was excellent and ahead of schedule with successful fieldwork and stakeholder workshop being held. Upon encouragement from the ITTO, a submission for additional funds was made and the EA was led to believe this would be successful. However, the ITTO financial impairment then occurred and the project was put on hold. This extended the project by over a year. Due to the multitude of uncertainties, the schedule for the project was subject to regular change and so performance against the original plan was poor.

3.4 Total amount of expenditures; analysis of applied input

The original budget included US$518,833 from the ITTO, of which US$432,244 would come to the EA. A further US$30,930 were to be contributed by the EA towards management costs

A project expansion was applied for in 2016 (encouraged by ITTO) which sought a total of US$766,744 from the ITTO, of which US$653,593 would come to the EA. A further US$30,930 were to be contributed by the EA towards management costs.

The final expenditure from the ITTO after revision to accommodate the financial impairment was US$512,154, of which US$426,280 came to the EA. A further US$123,496 was contributed towards management and operational costs, in the form of salary for Project staff.

Project Outcome, Target Beneficiaries Involvement

4.1 Extent to which the Project Specific Objective was achieved

As stated in section 3.1, the project performed moderately well against the specific objective (as specified in section 2.3) in that technological approaches for timber tracking systems using DNA fingerprints were developed and implemented in demonstration cases for important commercial species in Indonesia. However, the resolution and power of these DNA approaches could be improved through broader screening of the reference samples, and could be further validated through blind sample testing programs that had to be foregone due to the ramifications of the ITTO financial impairment. Similarly, implementation of these approaches could be more broadly and systematically adopted in Indonesian timber supply chains, beyond the demonstration cases achieved through this project.

4.2 Situation existing at Project completion as compared to the pre-Project situation

4.2.1 Tangible outputs

There are a range of tangible outputs from the Project that did not exist prior to its inception, these include:

- Optimisation of DNA extraction from timber approaches. See Technical Report on DNA Extraction Optimisation.
- Sequencing of the Shorea laevis genome. See Technical Report on DNA Profiling
- Extensive sampling of leaves, cambium and wood from Dipterocarpaceae in Kalimantan. See Technical Report on Sample Collection.

- Multi-species ddRAD data for 70 Dipterocarpaceae species to support further development and application of DNA barcoding approaches to timber identification. See Technical Report on DNA Barcoding.
- ddRAD data for Shorea laevis derived from 24 samples from across the range in Kalimantan, suitable for development of single nucleotide polymorphism markers (SNPs) for provenancing and DNA profiling of the species. See Technical Report on DNA Profiling.
- Demonstration of the use of DNA testing to support SVLK certification for access to international markets. See Technical Report on Industry Testing

4.2.2 Sectoral policies and programs

Within Indonesia the implementation of the SVLK framework has been a significant development towards putting in place an affordable traceability system for Indonesia forestry practises that can help identify the sustainability and legality of sources. Once this type of framework is in place then verification methods, such as DNA timber identification, can be implemented to check the validity of legality and/or sustainability/source claims.

4.2.3 The physical environment

The implementation of these policies is still in the early days, and there hasn't been enough time to monitor the effect on the legality of timber harvest activities in the region. The region still continues to experience heavy deforestation though and the rate of clearance hasn't changed since the start of the project.

4.3 Participation of the target beneficiaries

As identified in the original project document, the following stakeholders are considered the primary beneficiaries of the Project:

- Forest concessionaires

Participation: engaged through sampling campaign where sampling permission sought. Information on Project aims discussed. Future opportunities for concession holders to undertake or advocate for the use of DNA testing within their concession to demonstrate compliance.

- Timber trade federations and private companies

Participation: private companies engaged through workshop attendance and utilisation of DNA testing to demonstrate utility in Indonesian timber supply chains. Future opportunities to implement DNA testing and to engage with Project partners to identify new/additional requirements for development of future DNA identification resources for Indonesian timber.

- Indonesian government

Participation: engaged in all aspects of the project, planning, and sampling, participation in workshops and on steering committee. Law enforcement attended training. Future opportunities to implement DNA testing in support of SVLK and further incentivise timber industry to undertake independent verification of products.

- Certification organisations

Participation: Double Helix Tracking Technologies, providers of "CertiSource" certification were closely involved with the project and supported the provision of DNA testing services to industry. Future opportunities to further utilise DNA testing for broader customer base in Indonesia.

4.4 Project sustainability

The project has produced a significant resource of samples collected from the Dipterocarpaceae across Kalimantan. These samples, and the DNA extracted from them, will be kept indefinitely by the project partners for utilisation on futures projects. Additionally, the DNA sequencing and marker development work will also be available for future analyses.

The application of DNA barcodes to Dipterocarpaceae timbers in trade, for the purposes of providing additional support for SVLK certifications and allowing more accurate species determinations will continue.

Both UoA and CFBTI in FORDA intend to further the research as achieved in the Project through the support of PhD candidates who can take the development and applications further. UoA has a government funded doctoral candidate, Ms Melita Low who has already commenced her studies. In Indonesia, Ms. Purnamila Sulistyawati is currently applying for a funded doctoral position. At the final PSC meeting, both candidates were encouraged to consider applying for the ITTO fellowship programme.

Assessment and Analysis

The rationale and project identification process were adequate with appropriate stakeholder involvement. The definition of problems to be tackled, the Project Objectives and the choice of the implementation strategy were also appropriate (see section 2), although ultimately could not be fully realised due to the impacts of the ITTO financial impairment. The most critical differences between planned and actual Project implementation were the result of this impairment. The project was put on hold and funds were delayed and eventually reduced. During this time staff contracts had to be honoured according to Australian law. This put the project in significant deficit and meant that the planned activities had to be modified and scaled back. There was little that could have been done to anticipate or avoid this difficulty. Project inputs were initially appropriate, but fell short as a result of the ITTO financial impairment. Exacerbating this issue, was the unfortunate fact that the EA had been encouraged by the ITTO to apply for additional funds to extend the project by US$247,911. In expectation of this funding, decisions were made in the interests of time to expand the project – for example through additional sampling. Once the impacts of the impairment took effect, these additional expenses had already been expended, pushing the project further into deficit. Other risks identified to the project were either successfully mitigated (e.g. DNA extraction from timber) or no longer relevant as not part of the adjusted Project plan (e.g. scepticism by authorities mitigated through results of blind testing).

The Project enjoyed relatively good engagement with target beneficiaries (see section 4), however this was reduced somewhat due to the impacts of the ITTO financial impairment. The EA and partners see further engagement with stakeholders as a future priority in extension activities. Future development and application of the DNA tests resulting from the Project will have the potential to positively impact the target beneficiaries further. The original dissemination strategy intended to present the results of the work through published papers and conference proceedings. This strategy is still appropriate but will now take place once the work has been further developed and applied by the doctoral candidates working on the Project into the future.

The future sustainability of the project is currently secured through the appointment of a doctoral candidate in Australia with full scholarship from the Australian government, who will now work to further develop and apply the results of the Project. An additional doctoral candidate from Indonesia is also in the process of applying for a scholarship. CFBTI in FORDA, as part of the Indonesian Government, are well placed to promote and facilitate the continuation of the Project aims.

The roles of the EA and partners were appropriate for the Project, in particular CFBTI in FORDA was well placed to develop and implement the sampling campaign and DNA preparation. UoA was most technically advanced with access to state of the art laboratory facilities and DNA sequencing capacities. Other industry collaborators Double Helix Tracking Technologies were well placed with industry to provide perspective and access to forests, as well as customers interested in applying DNA analysis in their timber supply chains.

Lessons Learned

Table 3: Problems encountered and lessons learned

Problem Encountered	Lessons Learned
Early success of the project and indications from ITTO of further funding opportunities lead EA to commit to extension activities before funding was secure.	No funding should be relied upon until contracts are signed and funds have been received.
Lack of funds from ITTO stalled project but contracts for staff salaries at EA had to be honored. When project could recommence, staff were no longer employed on the project.	Due to EA flexibility it was possible to fund some additional staff time as extra in-kind contributions to the project. We cannot see how this situation could have been avoided without offering short and insecure contracts which do not attract or retain skilled staff.
Extensive additional unforeseen administrative burdens encountered, including poor handling of project setup by EA staff member (who was removed from project) resulting in updated project documents and budgets being required development of updated and expanded project proposal • development of updated and reduced project proposal requirement for updated contracts with funder and subcontractors Difficulties communicating effectively with EA finance and contracting teams in a timely manner	Greater resources required for administration of projects

Conclusions and Recommendations

The Project brought together knowledgeable, well connected and appropriate partners to undertake this ambitious project. After an initial great start, progress was significantly hampered by impacts of the ITTO financial impairment which delayed the project, caused salary costs to blow-out and resulted in reduced overall resources for the Project. Despite this significant setback, some progress was made against all outputs, yet there remains much to be done to fully realise the potential of the original (and the extended) Project plan.

A significant learning from the project was not to pre-empt funding, even when contracts are in place. The Project was running in deficit for most of its life due to this. In hindsight no funds should have been expended until they had cleared in the EA's accounts. Further, the administrative burden of the project amendments and associated requirements was not sufficiently accounted for in the budgeting.

As it stands, expansive sampling resources from the Dipterocarpaceae in Kalimantan were collected, DNA barcoding resources were developed for 75 species and DNA profiling resources for one species. Two workshops were held to disseminate project information and engage stakeholders in design and implementation. Three INTERPOL training workshops were attended and a study visit completed by an Indonesian researcher to Australian laboratories. DNA barcoding was implemented in exemplar meranti supply chains to support SVLK certification and improve access to international markets.

Looking towards future projects and the continuation of this work, the recommendations are:

1. Multispecies ID – Dipterocarpaceae

Analyse data from a genome screens for a subset of samples from an extensive collection of Dipterocarpaceae from Kalimantan. Identify loci that can distinguish species and then undertake the following:

- Develop a phylogeny based on these data
- Develop/apply a method to screen these loci in the remainder of samples, potentially NGS amplicon sequencing, MassArray genotyping, SNaPshot assay, or perhaps a hybrid capture approach.
- Test the identification capacity of the markers using blind test samples
- Optimise the test for use on timber extracted DNA in Indonesian labs (SNaPshot or some kind of restriction length polymorphism analysis on key SNPs)
- Demonstrate the applicability of the test in real life samples from trade

2. Single species ID and species comparisons – Shorea laevis (Bangkirai), Shorea parvifolia (Light red meranti)

Using existing collections undertake the following:

- Compare the genetic diversity and differentiation within S. laevis and S. parvifolia
- Determine whether patterns are similar for both species and the influence of life history traits and/or demography. Identify whether existing SNP markers developed from S. laevis are variable in other species and develop additional markers if required
- Determine whether genetic clustering can be used to accurately assign provenance to unknown samples for timber extracted DNA in Indonesian laboratories. Potentially collect more samples from across the region to include in the analysis
- Apply these techniques in partner laboratories overseas in an applied setting.

3. Genome annotation – Shorea laevis.

- Work on the annotation of the draft genome for S. laevis and use the results to support the above project components.

4. Capacity building and extension

- Train and develop capability/equipment in Indonesian lab
- Disseminate to government and industry – hold demonstration workshops with key stakeholders

It is also noted that all future collaborative projects must now obtain Indonesian Ministry of Finance sign off. This will likely lengthen the approvals process further and should be accounted for in time and resources when planning future projects.