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IDENTIFYING FRAMEWORK TREE SPECIES FOR RESTORING

FOREST ECO-SYSTEMS IN SIEM REAP PROVINCE

KIM SOBON

Thesis presented to the academic committee
in partial fulfillment of the requirements for
Degree of Master in Natural Resource Management
Batch I,
2011-2012

Phnom Penh, Cambodia

March, 2013

ROYAL UNIVERSITY OF AGRICULTURE

THESIS

ការកំណត់អត្តសញ្ញាណប្រភេទឈើឈានមុខសម្រាប់ស្តារប្រព័ន្ធអេកូឡូស៊ីព្រៃឈើឡើងវិញ នៅខេត្តសៀមរាប

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Kingdom of Cambodia

Nation Religion King

Ministry of Agriculture, Forestry and Fisheries

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KIM SOBON

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ABSTRACT

Deforestation and forest degradation are major concerns in Cambodia. Therefore, scientists must find new ways to restore degraded forest and/or forest ecosystem. The study, reported here identified framework tree species for restoring forest eco-systems in Siem Reap Province. It compared field performance among indigenous tree species, determined the degree to which each species met framework criteria and established appropriated standards for selecting framework tree species for restoring forest ecosystem.

The research was conducted at the Forest Restoration and Extension Station in Kulen Mountain Buffer Zone, FORRU-Cambodia's project site. Experimental field plots were established in 2010 and 2011. Vegetation surveys and soil sample analysis were conducted, before candidate framework tree species were planted and monitored for survival growth and response to fertilizer. Data analysis was carried out by MS Excel to analyze relative growth rates and SPSS 19.0 for ANOVA analysis.

Sixteen of the 19 species tested were considered suitable for planting to restore forest ecosystems in the northern part of the Siem Reap Province. Seven of the 16 had high field performance, with survival rates exceeding 70% after 18 months: *Gardenia sootepensis* Hutch, *Canarium subulatum* Guill, *Dalbergia cochinchinensis* Pierre, *Hopea odorata* Roxb, *Xylia xylocarpa* (Roxb.), *Sindora siamensis* Teysm. ex Miq.var. Siamensis, and *Sindora siamensis* Teysm .ex Miq.var.cochinchinensis. Nine other had medium field performance, with survival rates of 50-69%, but broad crowns and also scored as acceptable for planting for restoring forest ecosystem: *Afzelia xylocarpa* (Kurz) Craib, *Knema globularia* (Lam.) Warb, *Diospyros sylvatica* Roxb, *Diospyros ehretioides* Wall.ex G.Don, *Cratoxlum cohcinchinenesis*, *Gardenia angkorensisi*, *Walsura trichostemon* Miq, *Dioecrescis erythroclada* (Kurz) Tirv and *Hydnocarpus anthelmintica* Pierre ex Lanes.

In experimental plots 2010; Buffalo fertilizer (15-15-15) and organic fertilizer (10-5-2) significantly increased seedling survival rates. However, survival rates were not significantly different among species. One hundred grams of Buffalo fertilizer increased seedling survival more than 50g buffalo fertilizer and/or Taiwan organic fertilizer. Interactions between fertilizer treatments and species were not significant, indicating that differences among tree species were not affected by fertilizers. Fertilizer treatments significantly affected root caller diameter growth. In experimental plots 2011; Buffalo chemical fertilizer (16-16-8) and organic fertilizer (3-3-2) significantly increased seedling survival and contributed to significant differences among tree species. Fifty grams of buffalo fertilizer had a great effect on seedling survival than 100g buffalo fertilizer and organic fertilizer. However, interactions between fertilizer treatments and height and root caller diameter growth were not significant.

This research will be valuable for forest restoration programmes in Cambodia, and for the agencies that implement them: both the governments Forestry Administration of the Ministry of Agriculture, Forestry and Fisheries, Ministry of Environment and NGO's. It provides basic information to assist with decision making on species choices for the Siem Reap area and on experimental techniques to enable selection of species based on logical criteria for other areas.

ការកំណត់អត្តសញ្ញាណប្រភេទឈើឈានមុខសម្រាប់ស្តារប្រព័ន្ធអេកូឡូស៊ីព្រៃឈើឡើងវិញ នៅខេត្តសៀមរាប

គឹម សុបុណ្យ

អ្នកដឹកនាំនិក្ខេបបទ៖ បណ្ឌិត STEPHEN ELLIOTT
សហអ្នកដឹកនាំនិក្ខេបបទ៖ បណ្ឌិត សូ ធា
អ្នកជំនួយការនិក្ខេបបទ៖ បណ្ឌិត ហេង ចាន់ធឿន
សាលាក្រោយឧត្តម នៃសាកលវិទ្យាល័យភូមិន្ទកសិកម្ម

សង្ខេបនិក្ខេបបទ

ការបាត់បង់ព្រៃឈើ និងភាពសឹករិចរឹលព្រៃឈើគឺជាបញ្ហាចម្បងក្នុងប្រទេសកម្ពុជា។ ដូច្នេះអ្នកវិទ្យាសាស្ត្រត្រូវតែរកមធ្យោបាយថ្មីៗដើម្បីស្តារព្រៃឈើដែលបានរិចរឹល និង/រឺស្តារប្រព័ន្ធអេកឡូស៊ីព្រៃឈើឡើងវិញ។ ការសិក្សាត្រូវបានអនុវត្តនៅក្នុងខេត្តសៀមរាប ដើម្បីកំណត់អត្តសញ្ញាណប្រភេទឈើលូតលាស់លឿន រឺប្រភេទឈើឈានមុខសម្រាប់ដាំស្តារប្រព័ន្ធអេកូឡូស៊ីព្រៃឈើឡើងវិញ។ គោលបំណងនៃការសិក្សាគឺប្រៀបធៀបការដុះលូតលាស់នៅទីវាលរវាងប្រភេទឈើក្នុងស្រុក កំណត់កម្រិតលក្ខណៈវិនិច្ឆ័យសម្រាប់ប្រភេទឈើឈានមុខ និងបង្កើតនូវស្តង់ដារសមស្របសម្រាប់ជ្រើសរើសប្រភេទឈើលូតលាស់លឿនដើម្បីស្តារប្រព័ន្ធអេកូឡូស៊ីព្រៃឈើ។

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លទ្ធផលបង្ហាញថា ១៦ប្រភេទក្នុងចំណោម ១៩ប្រភេទឈើដែលបានដាំពិសោធន៍គឺជាប្រភេទឈើលូតលាស់លឿន ហើយសមស្របសម្រាប់ការដាំស្តារប្រព័ន្ធអេកូឡូស៊ីព្រៃឈើឡើងវិញនៅភាគខាងជើងនៃខេត្តសៀមរាប។ មានប្រភេទឈើលូតលាស់លឿនចំនួន ៧ ប្រភេទក្នុងចំណោម ១៦ប្រភេទដូចជា ដើមបាក់ដង (*Gardenia sootepensis* Hutch), តាឡាត់ (*Canarium subulatum* Guill), ដើមក្រញូង (*Dalbergia cochinchinensis* Pierre), ដើមគគីរ (*Hopea odorata* Roxb. var. odorata), ដើមសុក្រម (*Xylia xylocarpa* (Roxb.)), ដើមក្រកោះបន្លា (*Sindora siamensis* Teysm.ex Miq.var Siamensis) និង ដើមក្រកោះគ្មានបន្លា (*Sindora siamensis* Teysm.ex Miq.var cochinchinensis), មានអត្រារស់លើសពី ៧0% បន្ទាប់ពីដាំបាន ១៨ខែ ។ ដោយឡែក ៩ ប្រភេទផ្សេង

ទៀតដូចជា ដើមបេង (*Afzelia xylocarpa* (Kurz) Craib), ដើមស្មាក្របី (*Knema globularia* (Lam.) Warb), ដើមខ្ចាស់ (*Diospyros sylvatica* Roxb), ដើមល្មាំង (*Diospyros ehretioides* Wall.ex G.Don), ដើមស្លុកស្ពោរ (*Walsura trichostemon* Miq), ដើមល្ងៀង (*Cratoxylum cochinchinensis*), ដើមក្រំពុកក្រហម (*Dioecrescis erythroclada* (Kurz) Tirv.) ដើមដៃខ្លា (*Gardenia angkorensis* Pit) និងដើមក្របៅផ្លែធំ (*Hydnocarpus anthelmintica* Pierre ex Lanes.) ដុះលូតលាស់ជាមធ្យម និងមានអត្រារស់ចន្លោះពី ៥០ ទៅ ៦៩% ប៉ុន្តែមានកន្សោមស្លឹកធំ ដែលអាចទទួលយកបានសម្រាប់ការដាំស្តារប្រព័ន្ធអេកូឡូស៊ីព្រៃឈើឡើងវិញបានល្អ។

ចំពោះឡូត៍ពិសោធន៍ឆ្នាំ ២០១០ ជីក្បាលគោ (១៥-១៥-១៥) និងជីសរីរាង្គ(១០-៥-២) មានឥទ្ធិពលលើការអត្រារស់របស់កូនឈើ ប៉ុន្តែអត្រារស់ពុំមានភាពខុសប្លែកគ្នាទេរវាងប្រភេទឈើនិមួយៗ។ កម្រិតនៃការប្រើប្រាស់ជីក្បាលគោល ១០០ក្រាម បានបង្កើនអត្រារស់កូនឈើជាងការប្រើប្រាស់កម្រិតជីក្បាលគោត្រឹមតែ ៥០ក្រាម រឺ ប្រើប្រាស់ជីសរីរាងតែវ៉ាន់។ អន្តរកម្មរវាងប្រព្រឹត្តកម្មជី និងការលូតលាស់កំពស់នៃប្រភេទឈើពុំមានភាពខុសគ្នាជាអត្ថន័យទេ បង្ហាញថាការខុសគ្នានៃការដុះលូតលាស់របស់កូនឈើអាចទទួលឥទ្ធិពលជីដូចគ្នា រឺពុំទទួលឥទ្ធិពលពីការប្រើប្រាស់ជី។ ការលូតលាស់អង្កត់ផ្ចិតកូនឈើត្រឹមឬសមាសភាពខុសគ្នាជាអត្ថន័យ ហើយបង្ហាញថាជីមានឥទ្ធិពលលើការលូតលាស់អង្កត់ផ្ចិត។ ឡូត៍ពិសោធន៍ឆ្នាំ ២០១១ ជីក្បាលគោ(១៦-១៦-៨) និងជីសរីរាង្គ (៣-៣-២)មានឥទ្ធិពិលលើអត្រារស់របស់កូនឈើរវាងប្រភេទ និងប្រភេទ។ ជាលទ្ធផលនៃការពិសោធន៍បង្ហាញថាកម្រិតជីក្បាលគោ ៥០ក្រាម មានប្រសិទ្ធភាពជាងកម្រិតជីក្បាលគោ ១០០ក្រាម និងជីសរីរាង្គ។ ទោះបីជាយ៉ាងណាក៏ដោយ អន្តរកម្មនៃជីលើការលូតលាស់កំពស់ និងអង្កត់ផ្ចិតត្រឹមគល់ឬស ពុំមានប្រសិទ្ធភាពទេ។

ការសិក្សាស្រាវជ្រាវនេះមានតម្លៃចំពោះកម្មវិធីស្តារព្រៃឈើឡើងវិញក្នុងប្រទេសកម្ពុជា និងចំពោះភ្នាក់ងារអនុវត្តទាំងរដ្ឋបាលព្រៃឈើនៃក្រសួងកសិកម្ម រុក្ខាប្រមាញ់ និងនេសាទ ក្រសួងបរិស្ថាន និងអង្គការក្រៅរដ្ឋាភិបាលដ៏ទៃទៀត។ លទ្ធផលដែលបានរកឃើញនេះគឺជាព័ត៌មានមូលដ្ឋានដើម្បីជំនួសក្នុងការសម្រេចចិត្តថាតើគួរជ្រើសរើសប្រភេទឈើណាសម្រាប់ដាំស្តារព្រៃឈើក្នុងខេត្តសៀមរាប និងបច្ចេកទេសពិសោធន៍ ដែលអាចជ្រើសរើសប្រភេទឈើសម្រាប់ដាំទៅតាមលក្ខណៈវិនិច្ឆ័យ។

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LIST OF ACRONYMS

S1.B1	: Species number 1 and batch number 1
Cm	: Centimeter
Ha	: Hectare
M	: Meter
pH	: Potential Hydrogen
ANOVA	: Analysis of Variance
ANR	: Assisted Natural Regeneration
CF	: Community Forestry
CTSP	: Cambodia Tree Seed Projects
C&I	: Criteria and Indicator
FA	: Forestry Administration
FAO	: Food and Agriculture Organization of United Nation
FORRU-CMU	: Forest Restoration Research Unit-Chiang Mai University
FORRU-Cambodia	: Forest Restoration Research Unit-Cambodia
HND	: Hot Nitric Digest
GBH	: Girth at Breast Height
GPS	: Global Position System
ITTO	: International Timber Trade Organization
IUCN	: International Union for Conservation of Nature
JICA	: Japan International Cooperation Agency
NGOs	: Non-Government Organization
RBG	: Royal Botanical Garden
REDD	: Reduce Emission from Deforestation and Forest Degradation
RGR	: Relative Growth Rate
RHGR	: Relative Height Growth Rate
RRGR	: Relative Root caller Growth Rate
SD	: Standard Deviation
SPSS	: Statistic Package for Social Science
TNT	: Total Nursery Time

CHAPTER I

INTRODUCTION

1.1 Overview

Forests are invaluable natural resources, which provide many economic and social benefits such as timber and other forest products, watershed protection, mitigation of floods and droughts, carbon storage and wildlife habitats. Moreover, forests help to preserve culture, tradition and landscape. At present, forests in Cambodia are seriously threatened by economic land concessions, social land concessions and illegal encroachment for private ownership (Forestry Administration, 2010). Losses of all forest types threaten natural vegetation and wildlife habitats.

Deforestation and forest degradation are of major concern in Cambodia, as well as at the global level and efforts are being made to plant thousands of hectares of exotic and native species. To develop the national economy, alleviate poverty and, at the same time, ensure a sustainable supply of forest resources for future generations, community forestry has become a priority. Cambodia has recently introduced criteria and indicators (C&I), developed by ITTO, to report on progress toward sustainable forest management at national and forest management unit levels. However, currently few data on the performance and suitability of the vast majority of Cambodia's tree species for forest restoration have been collected. The need for further research, both on the ecology and horticulture of native forest tree species is immense.

One of the most promising methods of forest restoration is the framework species technique (Elliott et al., 2003). It involves planting the fewest number of tree species to catalyze biodiversity recovery. Framework tree species are native tree species with high survival and growth rates when planted out into deforested sites. They should have dense spread crowns, which shade out weeds and they should produce resources (flowers, fruits, nesting sites etc.), which attract seed-dispersing wildlife at an early age. The attracted wildlife completes the recovery of tree species richness by natural seed dispersal from nearby survival fragments of climax forest. However, at present it is not known which of Cambodia's indigenous forest tree species meet these criteria.

To address this problem, Cambodia's first Forest Restoration Research Unit (FORRU) was established in Siem Reap province in 2009, supported by the Darwin Initiative following the model developed at Chiang Mai University (FORRU, 2006). The unit is developing methods of restoring forest cover and biodiversity, using tree species characteristic of the local region. With technical support from Wildlife Landscapes in the UK, the unit initiated a research program to learn how to grow plant and take care of a wide range of indigenous forest tree species. The research covered forest phenology (to guide seed collection), seed germination, seedling growth and field performance of planted trees. The FORRU-Siem Reap project included construction of a research tree nursery in Banteay Srey District, establishment of field plots (in the same area) to identify framework tree species. The project has worked with FORRU-CMU and the Royal Botanic Gardens, Kew (RBG Kew) on species identification and seed technology.

1.2 Research Rational

- Currently reforestation projects in Cambodia are not being implemented on a scientific basis
- In Cambodia, few data are available to identify which native forest tree species meet framework species criteria.
- To restore forest cover, the framework species method is viewed as the most suitable technique, wherever forest fragments remain at the landscape level as a seed source for biodiversity recovery. It is particularly suitable for REDD+ projects currently being implemented by the government and NGOs. Since REDD+ combines biodiversity recovery with carbon storage, and framework tree species can do both with maximum efficiency.

1.3 Research Question

- How can Cambodia’s native tree flora be screened to identify potential framework tree species?
- Which native forest tree species, currently being tested at FORRU-Siem Reap, most closely match framework species criteria?
- What is the field performance of some potential framework tree species?

1.4 Goal and Objectives of Research

This study provides a quantitative assessment of the degree to which various tree species meet the field performance requirements framework species criteria and helps to establish appropriate standards for the selection of tree species to restore Cambodia’s tropical forest ecosystems and recover biodiversity. The objectives of the research are:

- to compare field performance among indigenous tree species by establishing a field trial plots system for testing candidate framework tree species to restore forest ecosystems in degraded forest;

- to determine the degree to which various tree species meet the field performance criteria of framework tree species, making them suitable for reforestation;
- to establish appropriated standards for selecting framework tree species for restoring forests ecosystem in Forest Restoration and Extension Station in Kulen Mountain Buffer Zone.

1.5 Research Hypothesis

Field performance data can be used to rank native forest tree species in order of their suitability as framework tree species.

1.6 Research Concepts

Figure 1.1 shows how the research was conducted. Framework tree species were identified using a field trial plot system to study field performance of 19 native forest tree species to determine whether they meet framework tree criteria? Success of the study depends on support from the local community, local forestry administration officers and relevant stakeholders.

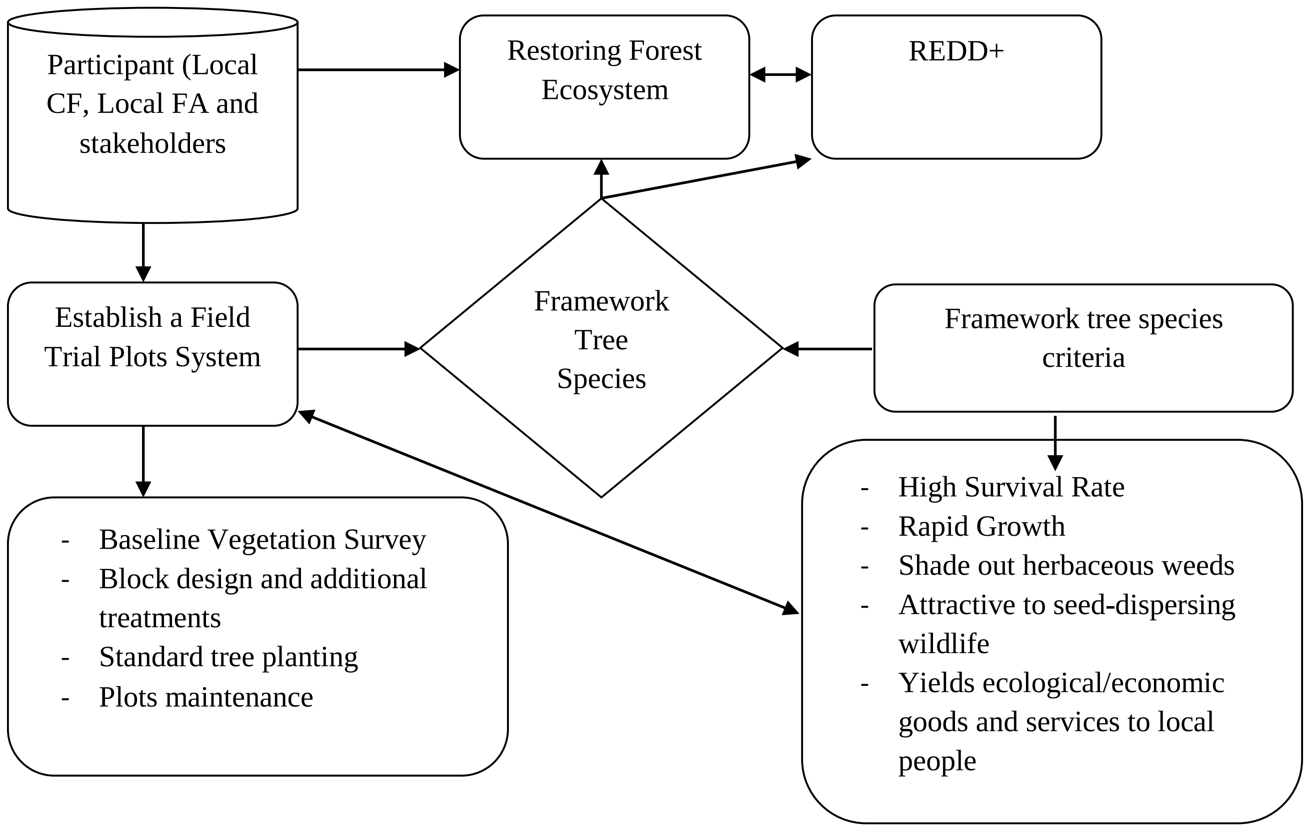

Figure 1.1: Conceptual framework of the research

1.7 Beneficiaries of Research

Forestry Administration, Community Forestry and relevant stakeholders can use result from the research to decide which tree species should be selected for restoring tropical forest. The research is also useful for university students to understand and make further research on other species or conduct their thesis research on the same site by using the result as baseline data.

1.8 Scope of the Research

This research took place in the Forest Restoration and Extension Station in Kulen Mountain Buffer Zone, Banteay Srey district, Siem Reap province. The research was conducted in an area of 6.1 hectare to test among 19 candidate framework tree species were tested. The experimental plots were established at the start of the rainy seasons of 2010 and 2011. The study focused on field performance of planted seedling such as survival rate, height and root caller diameter growth and crown canopy cover as affected by fertilizer application.

CHAPTER II

LITERATURE REVIEW

2.1 Key word definition

Framework Tree Species, Forest Restoration and Forest Eco-system

Framework Tree Species: are indigenous tree species with high survival, rapid growth and dense broad crowns (which shade out competing weeds) when planted on degraded forest land. They also provide fruit or other wildlife resources at an early age, to attract seed-dispersing wild animals and are resilient after forest fire.

The Forest Restoration Research Unit of the Chiang Mai University (FORRU-CMU) noted that framework tree species attract wildlife for seed dispersal, especially bats and birds (Elliot et al., 2006). Framework species are indigenous tree species planted in mixed stand to accelerate natural regeneration of forest and encourage biodiversity recovery. In Uganda the framework approach has been used to establish multipurpose tree gardens to conserve medicinal plant and provide local people with other needs, such as food and firewood (Torunn S., et. al., 2011).

Forest Restoration: "actions to re-instate ecological processes, which accelerate recovery of forest structure, ecological functioning and biodiversity levels towards those typical of climax forest", i.e. the end-stage of natural forest succession – relatively stable ecosystems that have developed the maximum biomass, structural complexity and species diversity that are possible within the limits imposed by climate and soil and without continued disturbance from humans. They represent the target ecosystem aimed for by forest restoration. Since the climate is a major factor that determines the composition of the climax forest, changes in the climate may result in a change in the climax forest type in some areas and thus the aim of restoration (Elliott et al., 2013 in press).

In order words, forest restoration is any set of activities to repair forest habitat or, restore forest structure and function (Krishnaswamy and Hanson 1999; Dobson et al., 1997). It is a complex task, complicated by diverse ecological and social conditions, that challenges our understanding of forest ecosystems, wherever biodiversity is one of the goals of reforestation, such as for wildlife conservation, environmental protection, eco-tourism or to supply a wide variety of forest products to local communities. It is most suitable for reforesting degraded sites within protected areas (S. Elliott & Cubitt, 2001). Forest restoration cannot re-establish all plant and animal species that lived in the original forest in a single step, since in most areas; the complete flora and fauna of the original forest are unknown. The success of forest restoration can be measured in terms of the return of a multi-layered canopy; increasing numbers of returning species (particularly rare or keystone species); improved soil conditions and so on. Therefore, forest restoration is a specialized form of reforestation (Elliott, 2000). Forest restoration may include passive protection of remnant vegetation or more active interventions to accelerate natural regeneration, as well as planting trees and/or sowing seeds (direct seeding) of species that are representative of the target ecosystem. However, wherever people live in or near the restoration site, economic species may be included amongst those planted in order to yield subsistence or cash-generating products. Economic indices of success may include the value of forest products and the ecological services generated (e.g. watershed protection, carbon storage etc.), which ultimately contribute towards poverty reduction (Elliott, 2000).

Forest Eco-system: is a terrestrial unit of living organisms (plants, animals and microorganisms), all interacting among themselves and with the environment (soil, climate, water and light) in which they live. The environmental "common denominator" of that forest ecological community is a tree, who most faithfully obeys the ecological cycles of energy, water, carbon and nutrients. A forest ecosystem would be considered having boundaries and would include a forest of trees out to the limit of tree growth. Forests are not the only ecosystems. There are hundreds of thousands of defined and undefined ecosystems that can cover the broadest to the tiniest of areas. An ecosystem can be as small as a pond or a dead tree, or as large as the Earth itself (Steve, N., 2012).

Figure 2.1: Forest eco-system – wildlife and seedling

Source: http://www.google.com.kh/search?

2.2 Forest Restoration Approach

2.2.1 Framework Tree Species Approach

The framework species approach to forest restoration was first conceived in Queensland, Australia (Goosem and Tucker, 1995; Lamb et al., 1997; Tucker and Murphy, 1997; Tucker, 2000). The method has since been adapted – to restore forest ecosystems in Thailand by the Forest Restoration Research Unit of Chiang Mai University, in North of Thailand. The unit developed framework species systems for upland evergreen and lowland deciduous forest types in northern Thailand and lowland evergreen forest in southern Thailand (FORRU, 2006). The framework tree species method is designed to restore ecosystem and recovery biodiversity in degraded forest area (FORRU-CMU, 2006). As recommendation from FORRU-CMU, the framework tree species approach needs some remaining forest trees, close to planted plots, to provide a source of seeds. The following show about the diagram of the framework tree species approach.

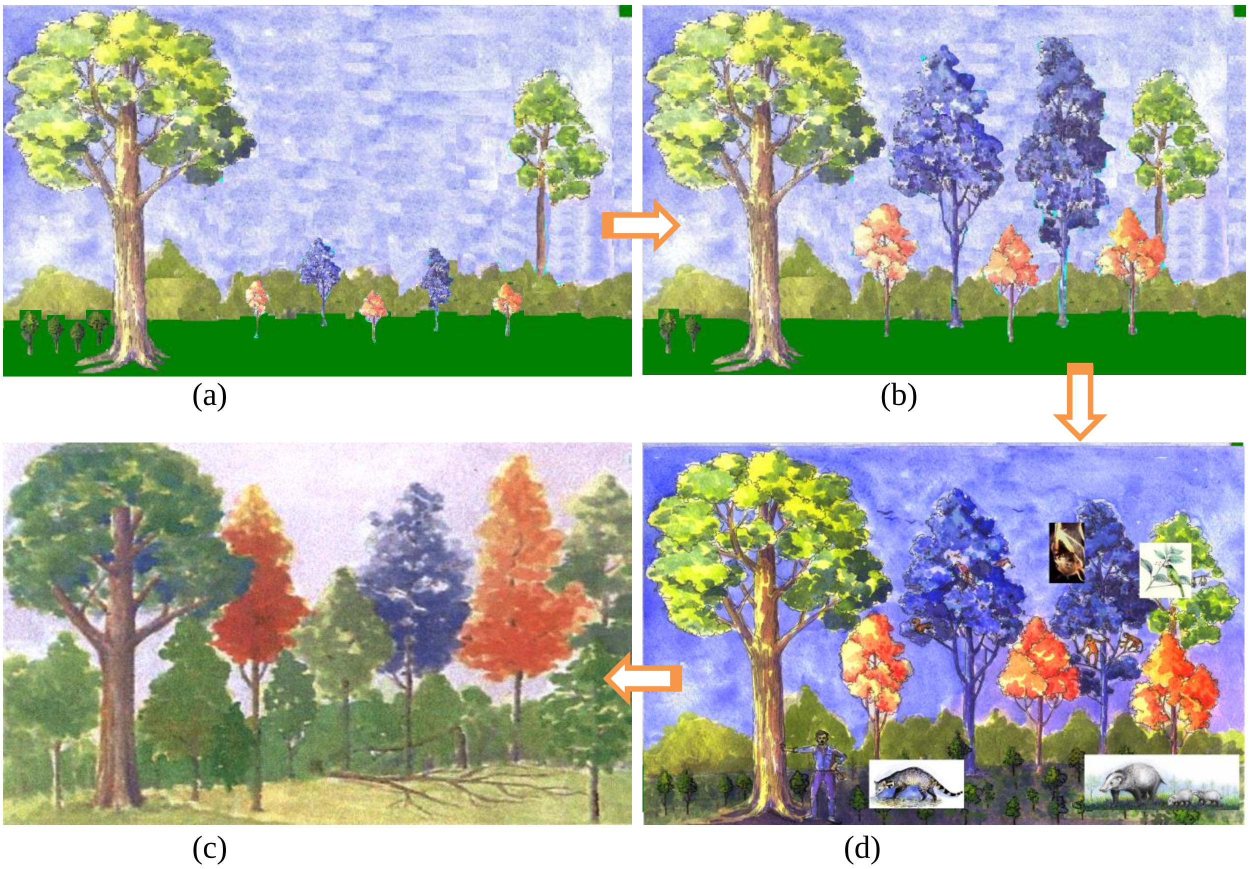

Figure 2.2: Framework tree species approach

Source: Forest Restoration Research Unit-CMU (2000) and CTSP (2005)

(a) Planted 20-30 native tree species, including both pioneer (indicated by blue saplings) and climax (indicated by red saplings) species, spaced 1.6-1.8m.

(b) The pioneer trees (Blue) grow rapidly and forming a top canopy. The climax trees are slower growing and forming an understory (Red).
(c) The pioneer trees (Blue) giving seed to attract wildlife (bird and animal) for seed dispersing. Seeds brought by wildlife were naturally germinated.
(d) After 10-20 year the pioneer trees begin to die, and then the climax trees will form the main canopy. The natural seed germinated will form an understory.

2.2.2 Assisted Natural Regeneration (ANR)

Assisted Natural Regeneration is a method for enhancing the establishment of secondary forest from degraded, grassland and shrub vegetation (FAO, 2012). This method was proposed by Dalmacio (1986), and its basic concept emphasizes protection and nurturing tree seedlings and saplings already existing on degraded sites, rather than establishment of entire new forest plantations (CTSP, 2005). In seriously degraded landscapes, ANR is not a feasible means for rehabilitation as it is likely that isolated trees do not produce viable seeds or vigorous seedlings.

ANR aims to accelerate, rather than replace, natural successional processes by removing or reducing barriers to natural forest regeneration such as soil degradation, competition with weedy species, and recurring disturbances (e.g., fire, grazing, and wood harvesting). Seedlings are, in particular, protected from undergrowth and extremely flammable plants such as *Imperata* grass. In addition to protection efforts, new trees are planted when needed or wanted (enrichment planting). With ANR, forests grow faster than they would naturally (FAO, 2012).

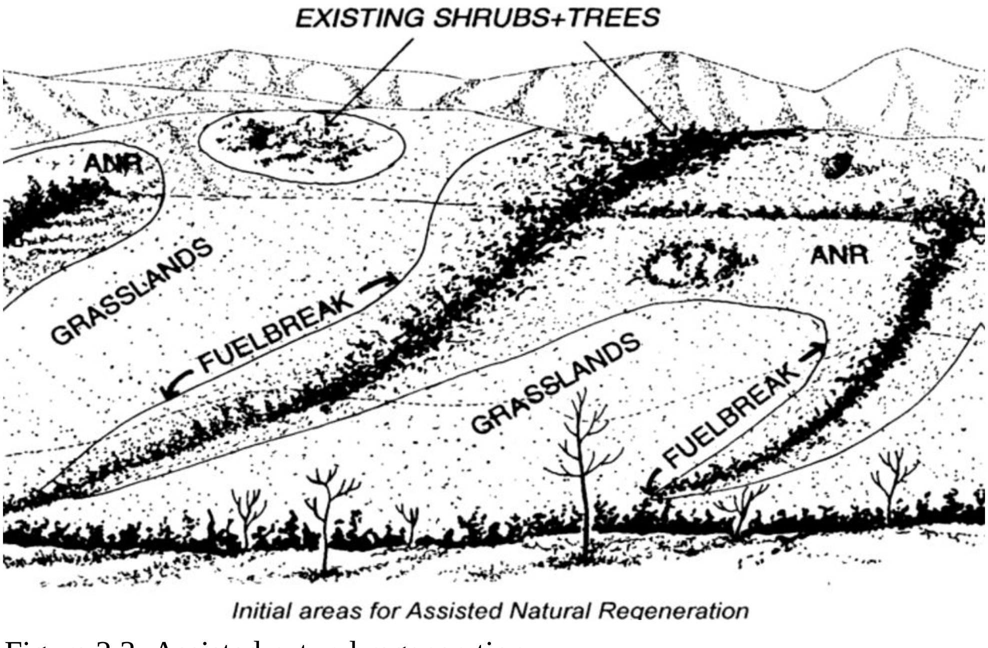

Figure 2.3: Assisted natural regeneration

Source: *Kathleen et al, 1999*

The benefit of using ANR is considered to:

- be a cost efficient way of regenerating forest, reduce reforestation costs, as there is less site preparation and nursery establishment
- provide job opportunities for communities, involve local people in rehabilitating a forest that meets their needs
- contribute to strengthening biodiversity, develop a forest with many layers of native species including shrubs and herbaceous plants
- provide hunting areas and
- Quickly restore forest cover to watersheds, multi-storey forests control soil erosion and increase the amount of rainfall absorbed through the ground and increase carbon sequestration and carbon sinks which contribute to climate change mitigation

2.2.3 Enrichment Planting

This method is commonly used in degraded forests (mainly evergreen or semi-evergreen forest), by planting economic indigenous tree species. Lesson learnt of the CTSP showed that dipterocarps have a wide range of survival rates and generally seedlings planted under partial shade survive better than those planted in open areas (CTSP, 2005). FORRU-CMU (2008) recommended that enrichment planting can be used alongside ANR, to increase the average density of treed seedlings and saplings to 3000 tree per hectare. If there are more than 3000 pre-existing regenerations tree per hectare, ANR can be used alone to re-establish forest cover (FORRU-CMU, 2005).

2.3 Forest restoration and biodiversity conservation

2.3.1 Forest restoration and local livelihood

The forest restoration depends on participation from local communities, because they depend on the forest resource for their subsistence and income. So to make sure that local people become involved with forest restoration activities, beneficial tree species for local livelihood should also be promoted (Thea So, 2011). FORRU-CMU in Thailand successfully engaged that local community of Ban Ma Sa Mai to become involved in both forest restoration and research to improve the framework species technique. Motivation for the villagers included improvement of watershed services and strengthening their right to remain living in a national park. (Elliott S. et al., 2012). In China, livelihood is priority they restore the biodiversity and productivity of forest because of livelihood benefits to the local poor (IUCN, 2012).

Elliott (2000) views forest restoration as a particular form of reforestation. It is exclusive of other forms of reforestation such as tree plantations and agro-forestry, although it may be combined with such forms. He suggested that the success of forest restoration programmes can be assessed in terms of gradually increasing levels of the following attributes: species richness and diversity indices of plants and animals; diversity of life forms; presence of keystone species; biomass and primary productivity; soil organic matter content and moisture holding capacity.

2.3.2 Succession Strategies for forest restoration

According to lessons learnt from Thailand, Myanmar and China, the success of forest restoration depends on the participation of local communities, local foresters and local authorities. In Myanmar, increasing depends on timber and firewood is becoming very important due to population growth (Sein Maung Wint, 2000). In Thailand, the purpose of forest restoration is to protect watershed and to reduce soil erosion and siltation. Incentives are very important to encourage local participation. Finally, the success of forest restoration also depends on adaptation of techniques suitable for the particular socio-economic and environment conditions found in each region and for each forest type.

2.3.3 Biodiversity conservation

Biodiversity conservation is of key importance to natural forest protection and reforestation; even monoculture tree plantations have some biodiversity value (Sayer et. al., 2004). Conservation of the biodiversity plays an importance role in the provision of ecosystem services to support sustainable development and poverty alleviation (Bullock et. al., 2011).

CHAPTER III

METHODOLOGY

3.1 Study site description

3.1.1 Siem Reap location

Siem Reap province is located in northwest Cambodia, where the 10,299 square kilometers of the total area. The province has share bordering to the North with Oddor Meanchey, to the East with Preah Vihear and Kampong Thom, to the West with Banteay Meanchey and to the South with the Tonle Sap Lake, a biggest water reservoir in the Southeast Asia. Siem Reap province has a famous temples, Angkor Wat, that more attractive for tourist.

In general, the Siem Reap province in the Southern part consists of the typical plain wet area for Cambodia, covering lots of rice fields and other agricultural plantations. The northern part is cover with forests such as evergreen, semi-evergreen and deciduous forest, where some area was became a degraded forest. The province has one an important small river, Siem Reap River, where flow from Phnom Kulen at the northern part and eventually into the Tonle Sap Lake.

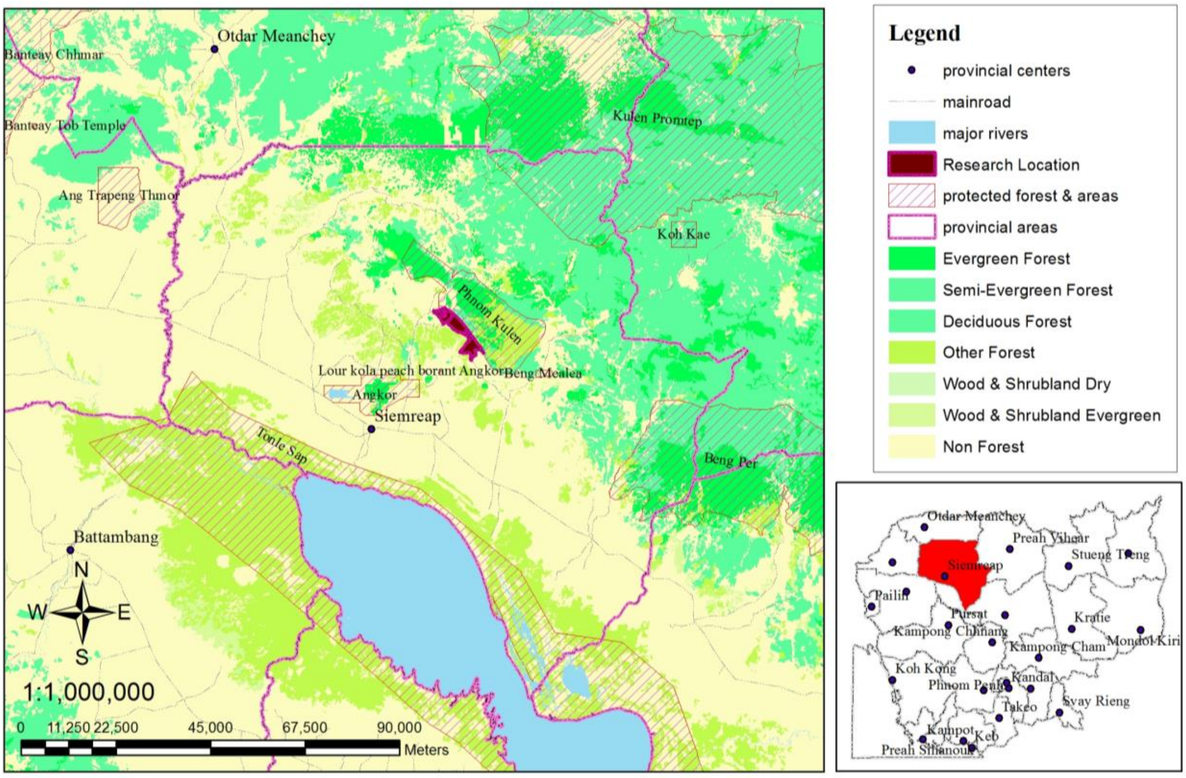

Figure 3.1: Map of Siem Reap province showing location of the research site,
Source: Forestry Administration, 2010

According to the statistic from Department of Meteorology, Ministry of Water Resource and Meteorology, Siem Reap features a tropical wet and dry climate. The province is generally hot throughout the course of the year, with average high temperatures never falling below 30 C° and low temperatures approximately 17 C° in every month (Appendix I). Siem Reap province has a relatively lengthy wet season which starts in April and ends in November. The dry season covers the remaining four months from December to March. The province averages (from 2007 to 2011) approximately 1,559 mm of rainfall per year. Mean relative humidity for an average year is recorded as 79.3% and on a monthly basis it ranges from 72% in March to 86% in September and October.

3.1.2 Site selection

The study site took place in Forest Restoration and Extension Station in Kulen Mountain Buffer Zone, Tbeing commune, BanteaySrey district, Siem Reap province. The station was started a FORRU's Siem Reap project on "Biodiversity recovery" in 2009, cooperation with FORRU-CMU and Kew RBG and sponsor by The Darwin Initiative, of the United Kingdom Government. The project established a field trial plots system in 2010 and expanded it in 2011 to test the field performance of 19 candidate framework tree species, in degraded forest and find out which species matched framework tree species criteria.

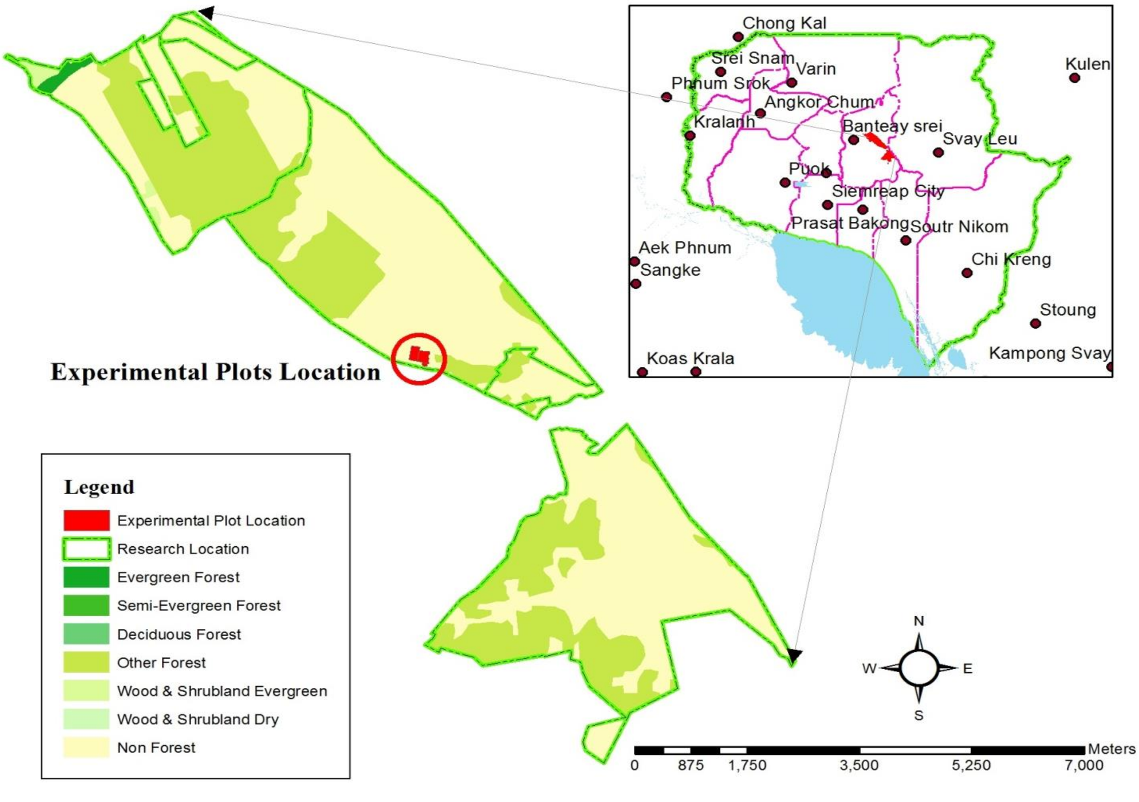

Figure 3.2: Map of the Forest Restoration and Extension Station in Kulen Mountain Buffer Zone, Banteay Srey district, Siem Reap province

3.2 Tree planting site assessment

3.2.1 Soil

Soil samples were collected from the plots (1 sample per plot, totally 12 samples) on 20/6/2010 and analyzed at the laboratory of the National Agriculture Laboratory of the Department of Agriculture, Phnom Penh. For nitrogen (N=0.061%) the Kjeldalh and sulfuric method was used, for phosphorus (P=0.024%) the hot nitric digest (HND) method and spectrophotometric method; and for potassium (K=0.003%), flame photometric where 1 mol. ammonium acetate pH=7. The soil was typical of lowland deciduous forest, with pH from 4.46 to 5.58 (Appendix II).

3.2.2 Rapid Site Survey

A baseline vegetation survey, using a participatory approach with local people, was carried out in May 2010 and April 2011. The boundaries of the site were marked on a map and GPS co-ordinates recorded. The vegetation survey was carried out using the following steps:

- Starting in one corner of the site, a bamboo pole was placed and a piece of string 5 m long (attached to the central pole) used to mark out a circular sample plot, radius 5 m.
- Within the circle, all trees, taller than 1 m, and live tree stumps were counted. Signs of fire or cattle, soil condition were noted and the cover and height of herbaceous weeds estimated (Appendix I – Rapid Site Assessment Form). All plots were photographed.
- Additional plot were placed 20 m apart along transect line with traversed the site at its widest point.
- Ten circle sample plots were fitted into the site.
- The average number of (trees >1m + live tree stumps) per circle was calculated and converted to an estimate of number of regenerates per hectare. The optimum spacing between trees is 1.8 m (3100/ha) (FORRU, 2006). Therefore the number of tree selected for planting per hectare was 3100 minus the number of natural regenerates.

Figures 3.3: Circular plots set up for vegetation survey

Source: Forest Restoration Research Unit-CMU, 2005

The survey results were used to decide how many trees and the balance between tree planting and ANR.

Table 3.1 Rapid site assessments for vegetation survey

Circle/Year	No. trees>1m tall (<30cm gbh)		No. live tree stumps		Total Source of regeneration	
	2010	2011	2010	2011	2010	2011
1	6	17	14	9	20	26
2	10	10	18	4	28	14
3	13	38	12	2	25	40
4	4	24	3	2	7	26
5	16	20	15	0	31	20
6	8	18	13	0	21	18
7	11	18	15	0	26	18
8	11	17	12	0	23	17
9	10	14	5	0	15	14
10	6	0	10	0	16	0
				Total	212	193
				Mean	21.2	19.3
		(=Mean x 10000/78)		Average/Ha	2717.95	2474.36

Source: First (2010) and second (2011) rapid site assessment by FORRU-Cambodia team

The survey indicated that in plot 2010, 280 tree/ha should be planted in the partially regenerating site to bring the density up to 3,000 per ha. We planted 360 trees per ha, resulting in an average spacing between trees of 1.8m; which is optimal for forest restoration to shade out weeds and close canopy rapidly (Appendix II).

On the completely cleared site (Plot 4), a total of 360 trees were planted (since there were no trees taller than 1 m on-site), spaced 1.8 m apart.

In experimental plot 2011, survey results indicated that 525 tree/ha should be planted to bring the density up to 3,000 per ha. But we planted a few more up to 600 trees per ha to meet the requirements of the experimental design (more detail please find in the appendix II).

Figure 3.4: Rapid site assessment before tree planting

3.2.3 Species diversity

According to historical information and the field site assessment the experimental area was completely degraded, due to encroachment for farming and settlement, land speculation and illegal logging. However, historical evidence suggested that the area was formerly covered in diverse evergreen or semi-evergreen forest, before 1973.

3.3 Experimental block design

3.3.1 Site preparation

The experimental site was demarcated, cleared of weeds and bamboo sticks placed to mark the tree planting points. An area of 3.25 ha of experimental plots in 2010 was divided into 4 blocks and 16 plots. Similarly 3 ha of experimental plots in 2011 were divided into 3 blocks and 12 plots. Each block was divided into 4 plots, 50m x 50m and 4 different colored poles used to make sure participants in the tree planting event, planted seedlings at right block and plots location (Figure 3.5). The trees planted in each of the plots are listed in Appendix V, along with the tree label numbering scheme.

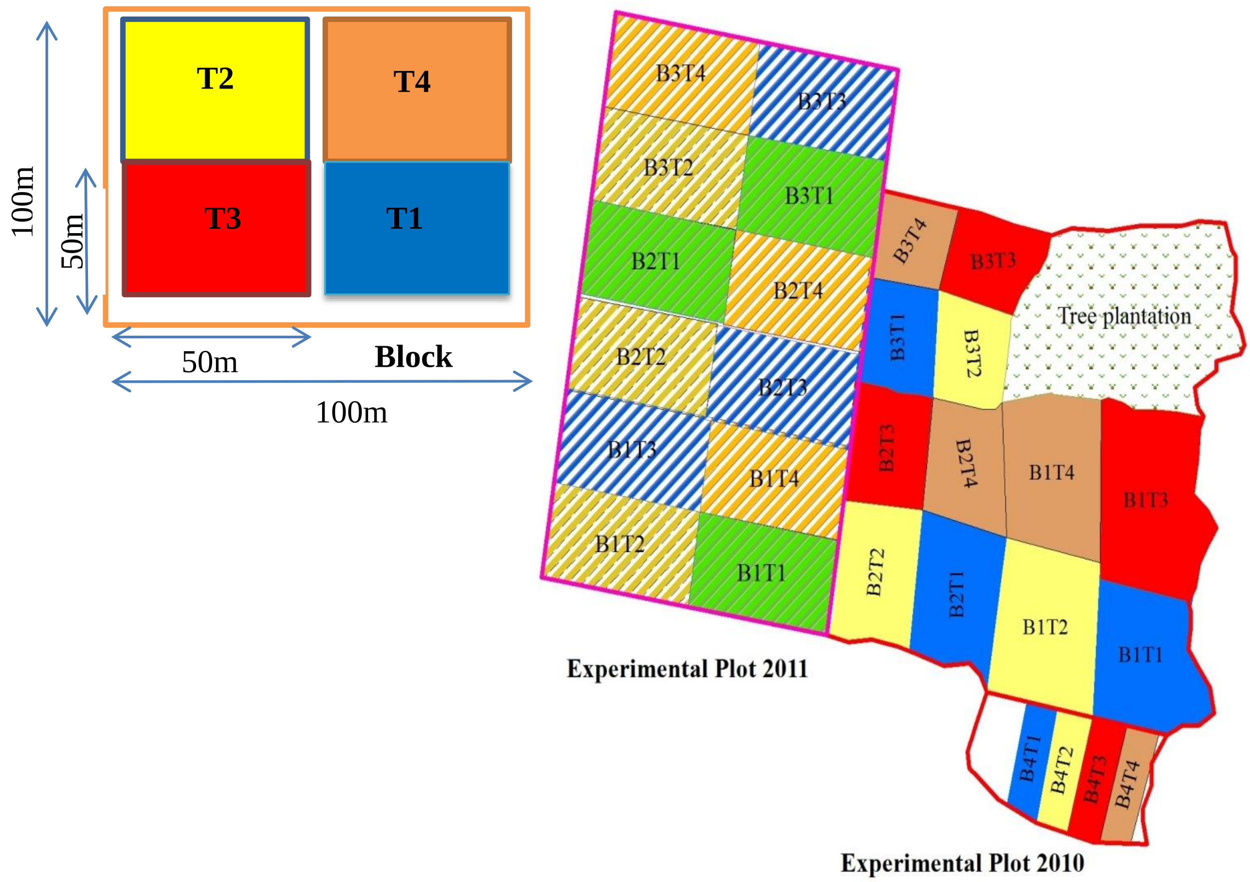

Figure 3.5: Map of planting site GPS locations – showing how each 1 ha block was subdivided into 4 plots each 0.25 ha each

Trees were grown in plastic bags from seed collected from natural forests close to the FORRU-Siem Reap nursery over 12-18 months prior to planting. They were hardened off by being removing the shade netting and by reducing watering starting from June 1st each year.

All seedlings were labeled and numbers and distributed to the sub plots according to color code. Local forester and communities were trained on how to plant tree and in application of appropriate treatments for each plot and the treatments applied were checked. In experimental plot 2010, only 5 trees were planted in the wrong plots. In experimental plot 2011, 30 trees were planted in the wrong plots.

Figure 3.6: Used bamboo stick to remark

Figure 3.7: Tree labeled, Species N°.Code N°

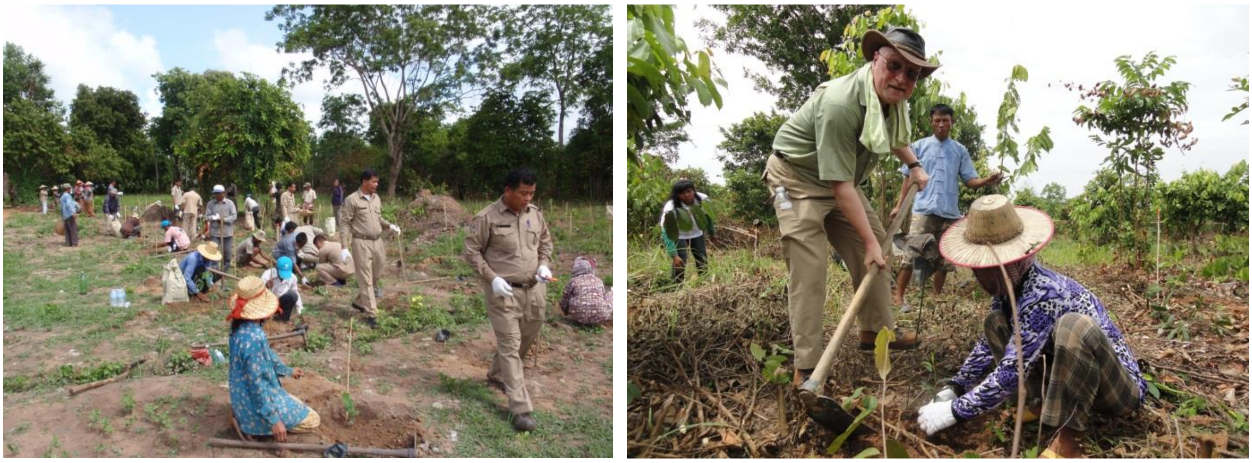

Figure 3.8: Tree planting event, experimental plots established

3.3.2 Tree species selection

Sixty tree species of potential tree framework species were germinated by FORRU-Cambodia's nursery, of which 19 species were selected to plant for testing for framework species characteristics, as shown in table 3.2 and table 3.3. Saplings of 2 additional species (*Afzelia xylocarpa* and *Hopea odorata*) are also available for planting in the natural regeneration plots (Plots 1-3) in 2010.

3.3.1.1 Experimental plot 2010

Table 3.2: Potential framework tree species planted in 2010

S.No	**Local name**	**Scientific name**	**Family**	**Number of seedlings planted**	
				(Plots 1-3)	(Plot 4)
S1.B1	Sdok Sdor	*Walsura trichostemon* Miq	Meliaceae	120	60
S7.B1	Krabav (big fruit)	*Hydnocarpus anthelmintica* Pierre ex Lanes.	Flacourtiaceae	120	60
S8.B1	Kokoh (Banla)	*Sindora siamensis* Teysm .ex Miq.var. Siamensis	Leguminosae, Caesalpinioideae	120	60
S12.B1	Talat	*Canarium subulatum* Guill	Burseraceae	120	60
S13.B1	Kokoh	*Sindora siamensis* Teysm .ex Miq.var.cochinchinensis	Leguminosae, Caesalpinioideae	120	60
S15.B1	Daikhla	*Gardemia angkorensis* Pit	Annonaceae	120	60
S16.B1	La ngeang	*Cratoxlum cohcinchinenesis*	Guttiferae, Hypericeae	120	-
S34	Beng	*Afzelia xylocarpa* (Kurz) Craib	Fabaceae	120	-
S35	Koki	*Hopea odorata* Roxb. var. odorata	Dipterocapaceae	120	-
		Total (9 species)		**1080**	**360**

Table 3.2; show that the total of 1,440 seedlings was planted into experimental plot 3.25ha in 2010. There were 9 species, 1,080 seedling planted into degraded forest at behind of the nursery. Otherwise, 360 seedlings was planted into open area since there were no trees taller than 1 m on-site), spaced 1.8 m apart.

3.3.1.2 Experimental plot 2011

Table 3.3 shows that a total of 1,800 seedlings were planted into 3ha of experimental plots in 2011. There were 10 species planted into degraded forest next after experimental plot 2010, spaced 1.8 m apart.

Table 3.3: Potential framework tree species planted in 2011

S.No	Local Name	Scientific Name	Family	N° of seedlings planted (Plots 1-3)
S6.B1	Sma Krobei	*Knema globularia* (Lam.) Warb	Myristicaceae	180
S10.B1	Krabav (small fruit)	*Hydnocarpus ilicifolia* King Common	Flacourtiaceae	180
S14.B1	Krang	*Lithocarpus polystachyus* (Wall. ex A. DC.) Rehd	Fagaceae	180
S17.B1	Krolanh	*Dialium cochinchinensis* Pierre	Leguminosae, Caesalpinioideae	180
S22.B1	Lamang	*Diospyros ehretioides* Wall.ex G.Don	Ebenaceae	180
S28.B1	Krom puk (Red)	*Dioecrescis erythroclada* (Kurz) Tirv.	Rubiaceae	180
S32.B1	Bak Dang	*Gardenia sootepensis* Hutch	Rubiaceae	180
S33.B1	So krom	*Xylia xylocarpa* (Roxb.)Taub.var kerrii	Leguminosae, Mimosoideae	180
S39.B1	Kchas	*Diospyros sylvatica* Roxb	Ebenaceae	180
S49.B1	Kra nhung	*Dalbergia cochinchinensis* Pierre in Lan.	Leguminosae, Papilionoideae	180
		Total (10 species)		**1,800**

3.3.3 Fertilizer treatments

According to tree planting plan and research methodology, fertilizer was applied three times per year in the rainy season at planting time and then every 3 month subsequently immediately after weeding.

Table 3.4: Fertilizer treatments

Treatment	Description of treatment	
	Experiment Plot 2010	**Experiment Plot 2011**
T1	100 g Buffalo Fertilizer(1)	50 g Organic(3)
T2	50 g Buffalo Fertilizer(1)	100 g Organic(3)
T3	100 g Taiwan Organic Fertilizer(2)	50 g Buffalo Fertilizer(4)
T4	50 g Taiwan Organic Fertilizer(2)	100 g Buffalo fertilizer(4)

Note: (1) Buffalo fertilizer N P K: 15-15-15

(2) Taiwan Organic fertilizer N P K: 10-5-2

(3) Organic fertilizer N P K: 3-3-2

(4) Buffalo fertilizer ($NP_2O_5K_2O$) N P K : 16-16-8

The treatments fertilizer emphasizes differences in Buffalo and Organic fertilizer formula between experimental plot 2010 and 2011. For more details see Appendix VI.

3.3.4 Standard Planting Method

The follow standard treatments were applied to all plots (as recommended by FORRU-CMU (2006) experiments) as follows. Bamboo poles were placed averaging 1.8 m from sources of natural regeneration in plots 1-3. Holes will be were dug with hoes approximately twice size of container in which the trees were grown (22.x 6.23cm. plastic bags) and 300g compost fertilizer will be was placed into each planting hole. Fertilizer treatments were applied as detailed below and then a circular corrugated cardboard mulch mat placed around each planted tree and pegged in place with the bamboo pole.

3.3.5 Involvement of local people in forest restoration

Some challenges were found during the project starting in 2009. Villagers needed land for settlement and agriculture behind the of FORRU-Cambodia nursery. So when the project started to plant seedlings to restore ecosystem in this area, a conflict occurred. If the seedlings had been planted without participation from those villagers, they might destroy the young trees, resulting in experiment failure.

Therefore, FORRU-Cambodia team negotiated, organized an extension and persuaded local people to become involved and made sure they understood what we were doing. Consequently, local people played an important role in protecting and maintaining the plots.

3.3.6 Plots Maintenance procedures

All plots were weeded and the fertilizer treatments repeated at 4-6-week intervals during the first and second rainy seasons after planting. Baseline monitoring for all plots was carried out one day after planting. Because of the extra funding support from FORRU-CMU and JICA, the experimental plots were protected from cattle, forest fire and human activities. A local villager was hired to patrol the experimental plots. In the experimental plots there was a lot of grass in the under storey, which could burn easily in the dry season, so forest fire break construction was implemented.

Figure 3.9: Fire breaks

Figure 3.10: Fence constructed to prevent cattle

3.4 Data Analysis

The health, survival and the growth of the candidate framework tree species were calculated as health average, percentage survival and relative growth rate (RGR) (Forest restoration research unit, 2008)

Relative Growth Rate (RGR), Height Relative Growth Rate:

RGR (% Increase height per year) = $\frac{lnh2-lnh2}{T2-T1}x100x365$

Where: RGR = Relative Growth Rate

H1 = Height of species in the first monitoring

H2 =Height of species in the Last monitoring

T2-T1 = Number of day between T1 and T2

ln = Natural Log

Health Average

Ha = (H1+H2+H3)/3

Where: Ha = Health Average

H1, H2, H3= Health score of plant species first, second and third survey

% Survival Rate

Percentage Survival Rate = (SN/TN) x 100

Where: SN = Number of Survival

TN = Total Number of Species

The data analysis of this research was used Microsoft Excel to analyze seedling performance, survival rate, relative height and root caller diameter growth rate and crown width. Then SPSS 19.0 software was used for One-way ANOVA analysis to compare the effectiveness of fertilizer on seedling growth.

CHAPTER IV

RESULTS AND DISCUSSION

4.1 Survival rate (%) of planted tree

Mean percent survival across blocks at the end of the 2nd growing season (18 months) averaged across all treatments for tree plant 2010 and 2011.

Table 4.1 Mean seedling survivals +/- standard deviation of the framework tree species

No.	Scientific name	Mean percent survival (%)		
		6 months	12 months	18months
Experimental Plots 2010				
1	*Walsura trichostemon* Miq	84.58 ±12.88	78.54 ±14.61	70.00 ±34.16
2	*Hydnocarpus anthelmintica* Pierre ex Lanes.	80.21 ±14.20	72.92 ±15.56	62.29 ±28.04
3	*Sindora siamensis* Teysm .ex Miq.var. Siamensis	86.67 ±11.16	81.88 ±14.89	71.67 ±28.60
4	*Canarium subulatum* Guill	88.33 ±12.86	72.92 ±22.54	71.04 ±34.60
5	*Sindora siamensis* Teysm .ex Miq.var.cochinchinensis	80.63 ±15.10	80.63 ±18.75	72.29 ±35.21
6	*Gardemia angkorensis* Pit	75.83 ±20.89	73.96 ±23.49	67.08 ±35.85
7	*Cratoxlum cohcinchinenesis*	77.71 ±18.39	74.38 ±20.11	70.21 ±31.37
8	*Afzelia xylocarpa* (Kurz) Craib	75.83 ±21.76	72.92 ±20.66	57.08 ±25.02
9	*Hopea odorata* Roxb. var. odorata	88.13 ±12.25	83.96 ±13.10	71.46 ±32.64
Experimental Plots 2011				
10	*Knema globularia* (Lam.) Warb	73.24 ±13.88	69.41 ±13.20	51.32 ±20.95
11	*Hydnocarpus ilicifolia* King Common	78.07 ±16.02	73.05 ±17.48	52.16 ±18.13
12	*Lithocarpus polystachyus* (Wall. ex A. DC.) Rehd	68.27 ±23.00	44.68 ±25.68	29.08 ±23.09
13	*Dialium cochinchinensis* Pierre	56.29 ±21.51	54.54 ±12.91	36.79 ±15.55
14	*Diospyros ehretioides* Wall.ex G.Don	59.79 ±16.50	55.29 ±21.16	39.44 ±16.98
15	*Dioecrescis erythroclada* (Kurz) Tirv.	74.81 ±16.65	73.45 ±11.00	58.25 ±13.57
16	*Gardenia sootepensis* Hutch	86.11 ±12.37	83.33 ±7.18	78.25 ±12.93
17	*Xylia xylocarpa* (Roxb.)Taub.var kerrii	88.02 ±8.91	86.98 ±10.02	70.79 ±13.55
18	*Diospyros sylvatica* Roxb	84.59 ±11.52	78.34 ±7.90	63.73 ±12.40
19	*Dalbergia cochinchinensis* Pierre in Lan.	92.37 ±10.33	92.50 ±11.44	87.15 ±8.63

Source: Tree survival in plots 2010 and 2011, Appendix V data analysis

Table 4.1 shows the mean percent survival +/- standard deviation of 19 candidate framework tree species 6 months, 12 months until the end of the second growing season after planting, 18 months, tested in the 4 blocks, 16 plots planted in 2010 and 3 blocks, 12 plots planted in 2011.

4.1.1 Tree plant 2010

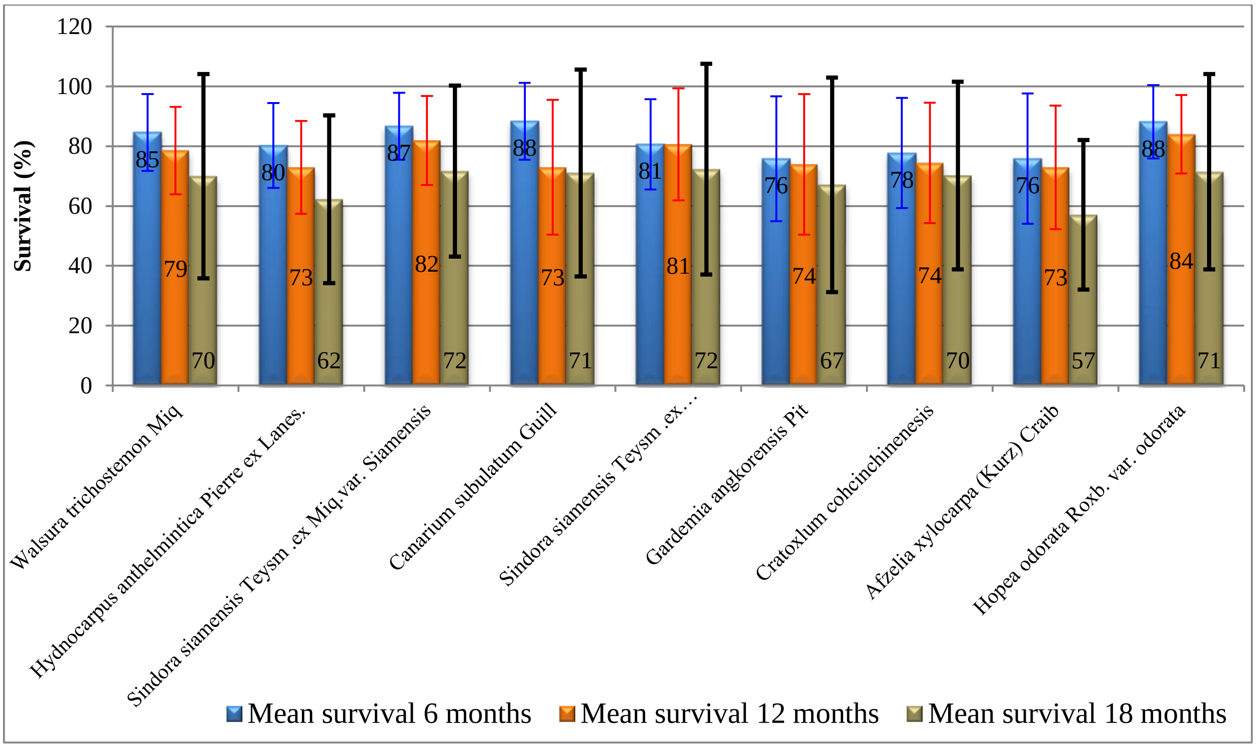

Figure 4.1: Mean survival of tree plant 2010, error bars represent +/- standard deviation

Six species out of the 9 tested achieved excellent survival rates higher than 70% 18 months after planting in 2010 i.e. *Walsura trichostemon* Miq, *Sindora siamensis* Teysm .ex Miq.var. siamensis, *S. siamensis* Teysm.ex Miq.var.cochinchinensis, *Canarium subulatum* Guill, *Cratoxylum cochinchinensis* (Lour.) Bl and *Hopea odorata* Roxb. var. odorata. Four species achieved acceptable survival rates of 50-69% *Hydnocarpus anthelmintica* Pierre ex Lanes, *Gardemia angkorensis* Pit, *Cratoxlum cohcinchinenesis* and *Afzelia xylocarpa* (Kurz) Craib.

a. *Canarium subulatum* Guill b). *Hydnocarpus anthelmintica* Pierre ex Lanes. c). *Walsura trichostemon* Miq

Figure 4.2: tree planted in 2010 plots, age 18 months

4.1.2 Trees planted in 2011

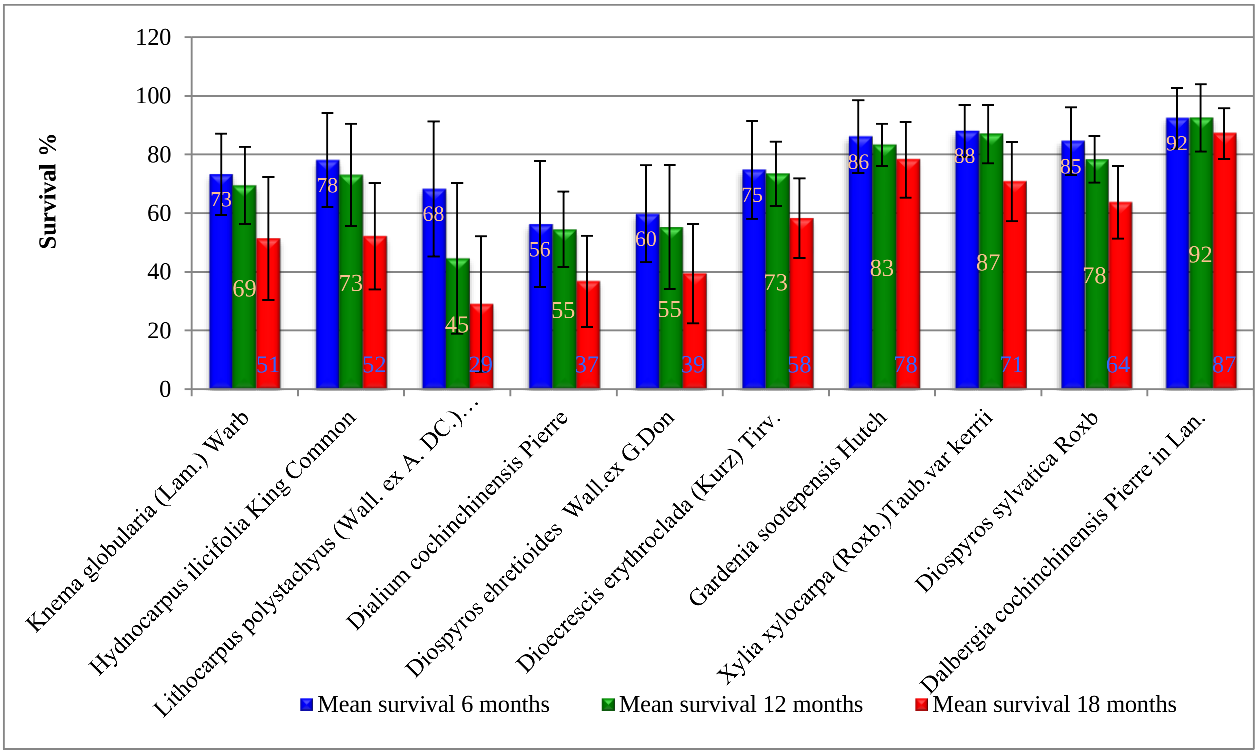

Figure 4.3: Mean survival of tree plant 2011, error bars represent +/- standard deviation

Three of the 9 species tested achieved excellent survival rates, higher than 70%, 18 months after planting in 2011 i.e. *Gardenia sootepensis* Hutch, *Xylia xylocarpa* (Roxb.) Taub. var .kerrii and *Dalbergia cochinchinensis* Pierre in Lan. Four had acceptable survival of 50-69%: *Knema globularia* (Lam.) Warb., *Hydnocarpus ilicifolia* King Common, *Diospyros ehretioides* Wall.ex G.Don and *Diospyros sylvatica* Roxb., whilst 2 species had unacceptably low survival below 50%: *Lithocarpus polystachyus* (Wall.ex A. DC.) and *Dialium cochinchinensis* Piere.

Gardenia sootepensis Hutch, *Dalbergia cochinchinensis* Pierre in Lan and its crown width

Figure 4.4: Trees planted in 2011 plots, age 18 months

4.2 Growth rate of planted tree

4.2.1 Tree height, root caller diameter and crown width

Table 4.2 shows height, root caller diameter and crown width, measured at the end of the second rainy season after planting. Five species displayed excellent growth, attaining mean heights of 1 meter or taller by the end of the second growing season: *Canarium subulatum* Guill, *Hopea odorata* Roxb. var. odorata, *Gardenia sootepensis* Hutch, *Xylia xylocarpa* (Roxb.)Taub.var .kerrii and *Dalbergia cochinchinensis* Pierre in Lan. For crown width, the ideal was 1.8 meter or more by the end of the second growing season (to achieve canopy closure) as recommended by FORRU, 2008. However, no species achieved the ideal and only 5 species can reached acceptable or marginally acceptable crown width of up to 1 meter such as: *Canarium subulatum* Guill, *Hopea odorata* Roxb. var. odorata, *Gardenia sootepensis* Hutch, *Xylia xylocarpa* (Roxb.)Taub.var .kerrii and *Dalbergia cochinchinensis* Pierre in Lan.

Table 4.2: Mean height, root caller diameter and crown width at 18months

No.	Scientific name	Height ±SD (Cm.)	RCD ±SD (mm.)	Crown Width ±SD (Cm.)
Experimental Plots 2010				
1	*Walsura trichostemon* Miq	28.98 ± 11.94	7.89 ± 3.31	33.98 ± 7.95
2	*Hydnocarpus anthelmintica* Pierre ex Lanes.	81.19 ± 25.28	10.33 ± 2.77	33.82 ± 9.74
3	*Sindora siamensis* Teysm .ex Miq.var. Siamensis	49.25 ± 17.06	8.41 ± 2.92	35.99 ± 10.38
4	*Canarium subulatum* Guill	109.57 ± 31.72	22.76 ± 7.10	81.25 ± 17.45
5	*Sindora siamensis* Teysm .ex Miq.var.cochinchinensis	43.43 ± 13.08	8.12 ± 3.99	35.02 ± 8.09
6	*Gardemia angkorensis* Pit	65.28 ± 16.06	11.48 ± 3.29	42.98 ± 6.90
7	*Cratoxylum cohcinchinenesis*	88.84 ± 29.20	10.79 ± 2.51	59.17 ± 13.69
8	*Afzelia xylocarpa* (Kurz) Craib	68.12 ± 21.80	12.45 ± 4.56	34.30 ± 11.90
9	*Hopea odorata* Roxb. var. odorata	108.21 ± 28.11	13.17 ±2.60	75.85 ± 18.23
Experimental Plots 2011				
10	*Knema globularia* (Lam.) Warb	61.53 ± 28	8.25 ± 3.15	40.02 ± 16.83
11	*Hydnocarpus ilicifolia* King Common	55.92 ± 21.86	7.88 ± 2.99	27.54 ± 11.97
12	*Lithocarpus polystachyus* (Wall. ex A. DC.) Rehd	55.07 ± 28.88	6.24 ± 3.30	32.46 ± 17.81
13	*Dialium cochinchinensis* Pierre	29.94 ± 15.38	4.39 ± 1.78	28.94 ± 31.41
14	*Diospyros ehretioides* Wall.ex G.Don	53.42 ± 14.03	7.66 ± 1.80	34.73 ± 9.51
15	*Dioecrescis erythroclada* (Kurz) Tirv.	39.83 ± 9.04	8.19 ± 1.34	23.47 ± 5.08
16	*Gardenia sootepensis* Hutch	135.57 ± 11.40	22.99 ± 1.79	74.20 ± 8.36
17	*Xylia xylocarpa* (Roxb.)Taub.var kerrii	115.84 ± 28.87	19.37 ± 4.64	61.62 ± 9.54
18	*Diospyros sylvatica* Roxb	56.41 ± 16.25	7.35 ± 2.91	36.23 ± 9.79
19	*Dalbergia cochinchinensis* Pierre in Lan.	124.63 ± 19.15	11.78 ± 1.55	62.15 ± 7.07

Source: Height, root caller diameter and crown width, appendix V

The remaining 14 species developed unacceptably narrow crowns that would require considerable further growth to close canopy and achieve weed cover reduction through shading.

4.2.2 Relative height growth rates

Relative height growth rate was calculated for each individual species that planted in 2010 and 2011 at 18 months. For trees planted in 2010 it was calculated for seedlings that survived over the period July, 2010 to November, 2011. For trees planted in 2011 it was calculated for seedlings that survived over the period July, 2011 to November, 2012.

Table 4.3: Relative height growth at 18 months

No	Scientific Name	TREATMENT				Species Means
	Experimental plots 2010	**T1 (BF:100g)**	**T2 (BF:50g)**	**T3 (TO:100g)**	**T4 (TO:50g)**	
1	*Walsura trichostemon* Miq	51.36±16.33	63.08±25.47	50.01±47.84	47.69±41.73	53.04±32.84
2	*Hydnocarpus anthelmintica* Pierre ex Lanes.	15.76±30.61	18.97±23.71	16.35±24.17	22.66±40.15	18.44±29.66
3	*Sindora siamensis* Teysm .ex Miq.var. Siamensis	52.33±24.37	52.19±19.94	56.61±8.16	49.29±23.62	52.61±19.02
4	*Canarium subulatum* Guill	52.51±21.95	57.68±12.12	60.59±20.30	55.71±23.78	56.62±19.54
5	*Sindora siamensis* Teysm .ex Miq.var.cochinchinensis	67.16±12.51	39.61±24.07	52.74±14.72	54.20±20.83	53.43±18.03
6	*Gardemia angkorensis* Pit	57.04±14.20	59.45±13.88	69.06±13.10	51.97±26.39	59.38±16.89
7	*Cratoxylum cohcinchinenesis*	27.29±15.78	50.38±29.05	41.11±41.40	41.13±27.82	39.98±28.51
8	*Afzelia xylocarpa* (Kurz) Craib	15.65±18.60[a]	29.54±7.45[b]	-8.39±16.29[ab]	37.40±13.97[ab]	18.55±14.08
9	*Hopea odorata* Roxb. var. odorata	33.34±4.55	13.30±14.67	19.27±12.38	22.63±9.96	22.13±10.39
	Treatment mean	41.38±17.66	42.69±18.93	39.71±22.04	42.52±25.36	41.57±21.00
	Experimental plots 2011	**T1(Org.:50g)**	**T2(Org.:100g)**	**T3(BF:50g)**	**T4(BF:100g)**	
10	*Knema globularia* (Lam.) Warb	47.91±38.41	50.69±24.23	51.51±48.24	77.87±13.33	57.00±31.05
11	*Hydnocarpus ilicifolia* King Common	22.87±10.43[a]	16.00±8.16[a]	6.74±6.40[a]	56.00±11.72[b]	25.40±9.18
12	*Lithocarpus polystachyus* (Wall. ex A. DC.) Rehd	14.62±35.90	48.88±3.86	2.76±4.78	67.82±67.44	33.52±28.00
13	*Dialium cochinchinensis* Pierre	44.22±12.21	34.21±18.41	55.77±9.97	37.40±12.39	42.90±13.25
14	*Diospyros ehretioides* Wall.ex G.Don	41.25±10.82	45.75±50.43	19.77±14.90	30.27±4.91	34.26±20.26
15	*Dioecrescis erythroclada* (Kurz) Tirv.	5.47±16.38	1.99±19.59	-16.77±11.36	-6.73±3.10	-4.01±12.61
16	*Gardenia sootepensis* Hutch	76.76±1.98	64.17±6.99	71.06±12.35	78.68±6.38	72.67±6.93
17	*Xylia xylocarpa* (Roxb.)Taub.var kerrii	41.25±24.16	34.31±11.25	38.34±10.99	38.66±8.43	38.14±13.71
18	*Diospyros sylvatica* Roxb	49.16±3.21	52.59±8.15	43.88±15.17	49.84±10.75	48.87±9.32
19	*Dalbergia cochinchinensis* Pierre in Lan.	91.93±1.47	84.84±20.09	71.70±23.15	96.44±14.82	86.23±14.88
	Treatment mean	43.54±15.50	43.34±17.12	34.48±15.73	52.62±15.33	43.50±15.92

Note: Value is replicated block means n=4±SD, 2010 plots and n=3±SD, 2011 plots. The letter “a” and “b” are used to show the significant different (p≤ 0.05) among the values within a column according to the one-way ANOVA testing. Values in the same column followed by the same letters are not significantly different.

An analysis of variance, on mean RHGR (%/Year) showed no significant differences among fertilizer treatments for two species: *Afzelia xylocarpa* (Kurz) Craib and *Hydnocarpus ilicifolia* King Common, (p=0.023 and at p=0.001, respectively). Averaging across species, for trees planted in 2010, highest growth was obtained with the Buffalo fertilizer (15-15-15) 50g treatment, 42.69%/year ±18.93, and lowest with Taiwan Organic fertilizer (10-5-2) 100g, 39.71 %/year ±22.04. In the 2011 plots, averaging across the species, highest growth was obtained with the Buffalo fertilizer (16-16-8) 100g, 52.62%/year ±15.33, and lowest with Buffalo fertilizer (16-16-8) 50g, 34.48%/year ±15.73.

4.2.3 Relative root caller diameter growth

Table 4.4: Relative root caller growth rate at 18 months

No	Scientific Name	TREATMENT				Species Means
	Experimental plots 2011	**T1 (BF:100g)**	**T2 (BF:50g)**	**T3 (TO:100g)**	**T4 (TO:50g)**	
1	*Walsura trichostemon* Miq	63.54±47.83	62.65±24.42	59.50±30.63	29.40±52.33	53.77±38.80
2	*Hydnocarpus anthelmintica* Pierre ex Lanes.	48.55±17.55	40.17±29.40	45.50±25.36	41.12±31.97	43.84±26.07
3	*Sindora siamensis* Teysm .ex Miq.var. Siamensis	63.20±31.16	45.05±44.14	64.94±17.79	45.02±30.24	54.55±30.83
4	*Canarium subulatum* Guill	130.73±24.29	104.90±52.35	123.87±22.74	99.92±49.66	114.85±37.26
5	*Sindora siamensis* Teysm .ex Miq.var.cochinchinensis	72.07±26.72	25.55±10.99	55.22±25.34	37.98±43.05	47.71±26.52
6	*Gardemia angkorensis* Pit	82.36±33.36	64.94±29.54	78.93±21.63	52.58±30.92	69.70±28.86
7	*Cratoxylum cohcinchinenesis*	98.06±24.06	60.46±35.43	83.95±15.27	80.06±10.43	80.63±21.30
8	*Afzelia xylocarpa* (Kurz) Craib	18.81±35.03	48.07±13.41	40.41±23.25	37.39±1.59	36.17±18.32
9	*Hopea odorata* Roxb. var. odorata	54.93±14.03	38.25±23.39	61.73±8.90	45.91±7.99	50.21±13.58
	Treatment mean	**70.25±28.23**	**54.45±29.23**	**68.23±21.21**	**52.15±28.69**	**61.27±26.84**
	Experimental plots 2011	**T1(Org.:50g)**	**T2(Org.:100g)**	**T3(BF:50g)**	**T4(BF:100g)**	
10	*Knema globularia* (Lam.) Warb	59.67±26.66	82.92±31.29	65.27±62.25	82.79±11.76	72.66±32.99
11	*Hydnocarpus ilicifolia* King Common	20.50±11.43	29.11±13.66	28.69±28.64	40.05±25.27	29.59±19.75
12	*Lithocarpus polystachyus* (Wall. ex A. DC.) Rehd	22.58±28.03^{a}	74.53±40.58^{ab}	0.08±0.15^{b}	49.89±22.56^{ab}	36.77±22.83
13	*Dialium cochinchinensis* Pierre	26.73±22.01	24.78±8.60	44.10±36.58	35.46±21.31	32.77±22.13
14	*Diospyros ehretioides* Wall.ex G.Don	27.14±4.55	22.02±28.72	14.68±5.14	27.53±11.98	22.84±12.60
15	*Dioecrescis erythroclada* (Kurz) Tirv.	1.70±6.62	10.28±6.38	5.14±11.31	13.58±2.49	7.67±6.70
16	*Gardenia sootepensis* Hutch	63.03±11.33	63.62±11.14	32.18±55.27	60.84±10.68	54.92±22.11
17	*Xylia xylocarpa* (Roxb.)Taub.var kerrii	52.25±27.04	47.11±14.09	35.33±19.01	50.65±17.80	46.34±19.49
18	*Diospyros sylvatica* Roxb	47.54±8.13	80.69±35.12	45.03±25.89	68.61±55.44	60.47±31.14
19	*Dalbergia cochinchinensis* Pierre in Lan.	99.30±22.93	115.29±14.44	84.30±5.16	108.78±16.37	101.92±14.73
	Treatment mean	**42.04±16.87**	**55.03±20.40**	**35.48±24.94**	**53.82±19.57**	**46.59±20.45**

Note: Value is replicated block means (n=3) ± SD. The letter “a” and “b” are used to show the significant different (p≤ 0.05) among the values within a column according to the one-way ANOVA testing. Values in the same column followed by the same letters are not significantly different.

Differences in RCD among treatments for each species, were not significant, except for *Lithocarpus polystachyus* (Wall. ex A. DC.) Rehd ($p \leq 0.05$). An averaging across all species, highest root caller diameter growth was obtained with the Buffalo fertilizer (15-15-15) 100g treatment, 70.25%/year ±28.23, and lowest with Taiwan Organic fertilizer (10-5-2) 50g, 52.15%/year ±28.69, for tree planted in 2010, whilst in the 2011 plots, highest growth was obtained with the Organic fertilizer 100g (3-3-2), 55.03%/year ±20.40, and the lowest with Buffalo fertilizer (16-16-8) 50g, 35.48%/year ±24.94.

4.3 Effective fertilizer on tree growth in the fields

4.3.1 Experimental plots 2010

Table 4.5: Survival rate, relative height and root caller diameter growth at 18 months (% / 18months)

Description		Survival (%)		RHGR (%)		RRGR (%)	
T1:100 g Buffalo Fertilizer (15-15-15)		80.00 ± 14.60^{a}		39.76 ± 24.18^{a}		62.01 ± 34.59^{a}	
T2:50 g Buffalo Fertilizer (15-15-15)		67.37 ± 20.88^{b}		37.94 ± 22.27^{a}		53.48 ± 34.57^{a}	
T3:100 g Taiwan Organic Fertilizer (10-5-2)		67.54 ± 20.45^{b}		34.30 ± 28.93^{a}		61.38 ± 27.14^{a}	
T4:50 g Taiwan Organic Fertilizer (10-5-2)		65.51 ± 23.24^{b}		33.56 ± 18.94^{a}		42.38 ± 32.83^{a}	
Analysis of Variance							
Source	d.f	F	Sig.	F	Sig.	F	Sig.
Treatment	3	3.635	**0.015**	0.414	0.743	2.151	0.098

Note: Value is replicated block means (n=4) ± SD. The letter "a" and "b" are used to show the significant different ($p \leq 0.05$) among the values within a column according to the one-way ANOVA testing. Values in the same column followed by the same letters are not significantly different.

Buffalo fertilizer (15-15-15) (100g) significantly increased tree survival rates, averaged across species. A *post hoc* test using SPSS 19.0 (multiple comparisons among treatments) indicated that this treatment significantly increased survival (P=0.015), compared with other treatments. However, differences among species survival rates (averages across all treatments) were not significant (P<0.05).

Tree height was not affected by fertilizer type. However, there was a significant difference in height among species. Interactions between buffalo chemical fertilizer and tree species and Taiwan organic fertilizer and tree species were not significant (P=0.743), indicating that differences in height among tree species were not affected by fertilizer treatment. Root caller diameter was not significant different among tree species, indicating that diameter was not significant affected by the interaction of buffalo chemical fertilizer (15-15-15), organic fertilizer (10-5-2) and tree species.

4.3.2 Experimental plots 2011

Table 4.6: Survival rate, height and root caller diameter growth at 18 months in experimental plots 2011

Description		Survival (%)		RHGR (%)		RRGR (%)	
Treatment							
T1: 50 g Organic (3-3-2)		62.84 ± 4.045 [a]		43.54 ± 5.537 [ab]		42.04 ± 5.726 [ab]	
T2:100 g Organic (3-3-2)		61.95 ± 4.424 [a]		43.34 ± 5.254 [ab]		55.03 ± 6.933 [a]	
T3:50 g Buffalo Fertilizer (16-16-8)		38.70 ± 5.119 [b]		34.47 ± 6.095 [b]		35.48 ± 6.686 [b]	
T4:100 g Buffalo fertilizer (16-16-8)		60.83 ± 3.713 [a]		52.62 ± 6.324 [a]		53.82 ± 6.093 [ab]	
Analysis of Variance							
Source	d.f	F	Sig.	F	Sig.	F	Sig.
Treatment	3	7.109	**0.000**	1.621	0.188	2.193	0.093

Note: Value is replicated block means (n=3) ± SD. The letter a, b, c and d are used to show the significant different ($p \leq 0.05$) among the values within a column according to the one-way ANOVA testing. Values in the same column followed by the same letters are not significantly different.

Buffalo chemical fertilizer (16-16-8) 100g and organic fertilizer (3-3-2) had a significant effect on the survival rate of candidate tree framework species in experimental plots 2011. Seedling survival rates were also significant differently among tree species too. The interaction of Buffalo chemical fertilizer (16-16-8) and tree species or organic fertilizer and tree species was significant (P=0.000), indicating that differences in survival rate among candidate tree framework species were due to buffalo chemical fertilizer (16-16-8) and organic fertilizer (3-3-2). *Dalbergia cochinchinensis* Pierre exhibited highest survival rate (81.03 ± 3.235), whilst, *Lithocarpus polystachyus* had the lowest 29.07 ± 6.40 (%). *Post hoc* multiple comparisons among treatments, in SPSS 19.0 indicated that 50g of buffalo fertilizer (16-16-8) resulted in significant lower survival (P=0.000).

Seedling height was not significant affected by Buffalo chemical fertilizer (16-16-8) and organic fertilizer (3-3-2), but there were significant differences among tree species. The interaction of Buffalo chemical fertilizer and tree species or organic fertilizer and tree species was not significant (P=0.188), indicating that the difference of height among tree species were not affected by Buffalo chemical fertilizer and organic fertilizer. Root caller diameters were also not significantly different P=0.093 among the fertilizer treatments, but there were significant differences among tree species. The interaction of Buffalo fertilizer and tree species or organic fertilizer and tree species was not significant; indicating that diameter was not affected by Buffalo chemical fertilizer and organic fertilizer.

4.4 Tree framework species that suitable for degraded forest restoration

4.4.1 Identifying of the species characteristic

The degree to which each species tested conformed to framework species characteristics was determined by means of a scoring system which converted data values into standardized scores for each of the characteristics for survival, growth, crown width, provision of resources to attract seed dispersers and ease of propagation. Mean values of seedling survival after 18months (%), height (cm) at 18 months and crown width (cm) at 18 months were converted into relative scores (i.e. % of the maximum recorded value). Total nursery time (from seed collection to dispatch of trees of a plantable size) was derived from nursery data from both FORRU-Cambodia and FORRU-CMU research nurseries. Furthermore, species received extra score if they produced fleshy fruits likely to attract seed-dispersing animals. For species that survival lowers than 50% was rejected. The data upon which scores were calculated are presented in Table 4.7.

Table 4.7: Species characteristic

S.N	Scientific Name	Survival (%)	Average Height (Cm)	Crown Width(Cm)	Fleshy Fruit	TNT
1	*Walsura trichostemon*	70	29	34	Yes	< 1 Yr
2	*Hydnocarpus anthelmintica*	62	81	34	No	< 1 Yr
3	*Sindora siamensis* (Banla)	71	49	36	No	< 1 Yr
4	*Canarium subulatum* Guill	71	109	81	Yes	< 1 Yr
5	*Sindora siamensis* (Khnam banla)	72	43	35	No	< 1 Yr
6	*Gardemia angkorensis*	67	65	42	Yes	< 1 Yr
7	*Cratoxlum cohcinchinenesis*	70	88	59	No	< 1 Yr
8	*Afzelia xylocarpa*	57	68	34	No	< 1 Yr
9	*Hopea odorata*	71	108	76	No	< 1 Yr
10	*Knema globularia* (Lam.) Warb	51	61	40	Yes	1-2 Yr
11	*Hydnocarpus ilicifolia*	52	56	27	No	1-2 Yr
12	*Dioecrescis erythroclada*	58	40	23	Yes	< 1 Yr
13	*Gardenia sootepensis* Hutch	78	135	74	Yes	< 1 Yr
14	*Xylia xylocarpa* (Roxb.)	71	115	61	No	< 1 Yr
15	*Diospyros sylvatica* Roxb	64	56	36	Yes	<1 Yr
16	*Dalbergia cochinchinensis* Pierre	87	124	62	No	< 1 Yr

Source: FORRU-Cambodia's and FORRU-CMU's databases

4.4.2 Scoring system to select tree framework species

Group discussions among local foresters, local community representatives and FA's officials identified six parameters to include in the scoring system i.e. survival, height, crown width, attractiveness of the animal, tree propagation in nursery and economic value. The discussion also determined the weight assigned to each parameter, according to what the participants thought was most importance. Seedling survival and economic value were given a 200% weighting (i.e. score x 2), height and crown score were assigned 150% (i.e. height x 100/highest height) and attractiveness to wildlife and ease of propagation were assigned a weighting of 100% (i.e. no multiplier of the score). The economic values based on use value of the community consumption such as house construction, furniture, fence and traditional medicine, rarely and endanger species that prohibited and protected by government (i.e. timber or big tree given 150-200%, small tree given 100-149%, pole tree given 50-99% and fuel wood given 0-49%).

Table 4.8: Species suitable scoring system

Species Name	Survival Score	Height Score	Crown Score	Attractive Score[(a)]	Propagation Score[(b)]	Economic Score	Total Score	Adjusted Score	Rank
Max.	**200**	**150**	**150**	**100**	**100**	**200**			
Gardenia sootepensis Hutch	156	150	137	100	100	150	793	100	**1**
Dalbergia cochinchinensis Pierre	172	138	115	0	100	200	725	91	**2**
Canarium subulatum Guill	142	121	150	100	100	90	703	89	**3**
Hopea odorata	142	120	141	0	100	160	663	84	**4**
Xylia xylocarpa (Roxb.)	142	128	113	0	100	160	643	81	**5**
Gardemia angkorensis	134	72	78	100	100	100	584	74	**6**
Sindora siamensis (Banla)	142	54	67	0	100	180	543	68	**7**
Sindora siamensis (Khnam banla)	144	48	65	0	100	180	537	68	**8**
Afzelia xylocarpa	114	94	63	0	100	180	551	69	**9**
Cratoxlum cohcinchinenesis	140	98	109	0	100	70	517	65	**10**
Knema globularia (Lam.) Warb	102	68	74	100	75	100	519	65	**10**
Diospyros sylvatica Roxb	128	62	67	100	100	50	507	64	**12**
Walsura trichostemon	140	32	63	100	100	50	485	61	**13**
Hydnocarpus anthelmintica	124	90	63	0	100	80	457	58	**14**
Dioecrescis erythroclada	116	44	43	100	100	40	443	56	**15**
Hydnocarpus ilicifolia	104	62	50	0	75	80	371	47	**16**

Note: (a) Fleshy fruits: 100, Dry fruits: 0

(b) Propagation score: TNT<1Yr: 100, 1-2Yr: 75, >2Yr: 50

For the scoring system, we followed steps recommended by Elliott et al. (2008). The results of the scoring system are shown in Table 4.8. Species with total adjusted score higher that 70/100 are considered to be effective framework tree species, suitable for restoring lowland forest in Siem Reap province. A species with scores of 50-69% are considered acceptable, whereas those with scores lower than 50% were deemed unsuitable, although their suitable might be improved with increasing the quality of the planting stock or intensifying aftercare treatments.

4.5 Discussion result from research

4.5.1 Tree framework species selection

Gardenia sootepensis Hutch, *Canarium subulatum* Guill, *Dalbergia cochinchinensis* Pierre, *Hopea odorata, Xylia xylocarpa* (Roxb.), *Sindora siamensis* (Banla), *Gardemia angkorensis* and *Sindora siamensis* (Khnam banla) are all suitable for restoring lowland deciduous forests in Siem Reap province, as well as similar ecological zones elsewhere.

Species with medium growth but broad crowns may also be acceptable for planting, if mixed in with other high performing species: i.e. *Afzelia xylocarpa*, *Knema globularia* (Lam.) Warb, *Dialium cochinchinensis* Pierre, *Diospyros sylvatica* Roxb, *Walsura trichostemon*, *Diospyros ehretioides*, *Cratoxlum cohcinchinenesis*, *Dioecrescis erythroclada* and *Hydnocarpus anthelmintica*. *Hydnocarpus ilicifolia* and *Lithocarpus polystachyus* both had low survival and growth and cannot be recommended for planting.

These results apply only to lowland deciduous forest in the northern part of Siem Reap province. Further testing would be needed to determine if these species are suitable for other sites.

4.5.2 Effectiveness of fertilizer on seedling performance

As indicated in table 4.5 and table 4.6, fertilizers had a significant effect on seedling survival ($p \leq 0.05$), but not on height/diameter growth. This result may be related to the weather condition of the experimental area. Temperature, rainfall, humidity and soil condition all effect seedling growth particularly in degraded forest.

In degraded forest with similar weather conditions, these framework tee species can be used with similar fertilizer treatments to good effect. FORRU-CMU (2006) also reported that fertilizer is important in enabling young trees to successfully overtop weeds and rid themselves of competition within 2 years after planting.

Over almost 2 years of testing 19 candidate tree framework species, sixteen were found to be suitable as framework species. There were 16 of the 19 species is a framework tree species that suitable to plant into degraded forest in Siem Reap province. However, to make sure among 16 framework tree species really easy adapting to other ecological zone, a further research is need.

4.5.3 Challenges from research

There were several challenges encountered whilst conducting this research including funding shortage, forest land encroachment by migrant people, cattle problems and long distance of experimental plot location far from Phnom Penh.

Funding shortage was dealt with by applying for additional funding from JICA. Success of the project relied on supplementary support from JICA to maintain the experimental area following the end of Darwin funding.

Forestland encroachment and cattle problems are very sensitive issues that affect seedling performance in the experimental plots, if not managed well. Co-operation of local people was encouraged by involving them directly in planting plot establishment (tree planting and by employing them to help with monitoring tree). Cattle were excluded from the site by a fence, although some cattle damage was incurred before the fence was finished.

CHAPTER V

CONCLUSION AND RECOMMENDATION

5.1 Conclusion

Sixteen of the 19 species of candidate framework species tested were acceptable for planting to restore lowland deciduous forest in northern Siem Reap Province. Seven (*Gardenia sootepensis* Hutch, *Canarium subulatum* Guill, *Dalbergia cochinchinensis* Pierre, *Hopea odorata* Roxb., *Xylia xylocarpa* (Roxb.), *Sindora siamensis* Teysm. ex Miq. var. Siamensis, and *Sindora siamensis* Teysm. ex Miq. var. Cochinchinensis had high growth, with survival rates higher than 70%, but narrow crowns that would require considerable further growth to get close canopy within 18 months after planting. Another 10 species (*Afzelia xylocarpa* (Kurz) Craib, *Knema globularia* (Lam.) Warb, *Dialium cochinchinensis* Pierre, *Diospyros sylvatica* Roxb, *Walsura trichostemon*, *Diospyros ehretioides*, *Cratoxlum cohcinchinenesis*, *Dioecrescis erythroclada, Gardenia angkorensis* and *Hydnocarpus anthelmintica*) had medium field performance, with survival rates of 50-69% and broad dense crowns and were deemed “acceptable” acceptable for planting especially if mixed with some of the higher performing species.

An experimental plots 2010; Buffalo fertilizer (15-15-15) and organic fertilizer (10-5-2) had a significantly increase the survival rate of seedlings, but survival rates did not different significantly among tree species. By using a Turkey test in the one-way ANOVA in SPSS 19.0 indicated that 100g of Buffalo fertilizer (15-15-15) increased seedling survival than 50g buffalo fertilizer (15-15-15) and/or Taiwan organic fertilizer (10-5-2). Interaction between fertilizer treatments and tree species were not significant, indicating that differences among tree species were not affected by the treatments. However, for root caller diameter, interactions were significant meaning that fertilizer affected root caller diameter growth.

In experimental plots 2011, Buffalo chemical fertilizer (16-16-8) and organic fertilizer (3-3-2) significantly increased seedling survival in the field plot trial system, due to significant differences among tree species. Fifty grams of buffalo fertilizer had more effectively on seedling survival (P=0.000) than 100g buffalo fertilizer and organic fertilizer. However, the interaction of fertilizer on height and root caller diameter growth was not significant.

This research will be valuable for forest restoration programmes in Cambodia, and for the agencies that implement them: both governments Forestry Administration of the Ministry of Agriculture, Forestry and Fisheries, Ministry of Environment and NGO’s. It provides basic information to assist with decision making on species choices for the Siem Reap area and on experimental techniques to enable selection of species based on logical criteria for other areas.

Forest restoration by the framework species method is a new technique for Cambodia. It can be used successfully in study area because of its use of indigenous species which were present historically and are genetically adapted to the area. With high survival rate, rapid growth, and development of crowns capable of shading out herbaceous weeds, the method can create a young forest, remove invasive species and maintain or recover biodiversity. Finally the species tested were suitable for areas with temperatures of 17-30°C, rainfall 1,559mm/year, and humidity from 72-86%. For soil condition is lowland deciduous forest soil, pH from 4.46 to 5.58.

5.2 Recommendations

In accordance with the result of this research, I would like to give some suggestion or recommendation as follow:

- The 16 framework tree species discovered from the experimental plots are suitable for the Northern part of Siem Reap Province. Further research is needed to determine if the species can used under different ecological conditions.
- Development of the framework species method requires long term research, so all institutions related to forestry sector should support students or young researchers to continue to develop this line of research.
- If possible, the Forestry Administration should be allocate new funding support to expand the framework tree species method to test it in different ecological zone and carry out further research to identifying more researching a new indigenous species capable as acting as framework tree.

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