A REPORT ON

CLIMATIC SIMILARITIES & SPECIES SITE CONDITIONS: A PREREQUISITE TO INTRODUCING

PLANTATION SPECIES TO WAWOI-GUAVI TRP AREA AND ELSEWHERE

…………***Select*** …….………….***Plant***…………………………..***and Harvest***……..

IN PAPUA NEW GUINEA

An Initiative by Rimbunan Hijau (PNG) Group Demonstrating its Continued Commitment to Sustainable Forest Management in Papua New Guinea Through Reforestation

1.0. INTRODUCTION

Introducing new species to new site is complex and often a lengthy process is involved. However, a quicker way would be to compare climatic similarities with site conditions and introduce species that can thrive well on the site. This holds the basis for this report where comparison is made on climate and site conditions of Ulabo (Milne Bay), SBLC (West New Britain) and Lae (Morobe Province) with those of Kamusie (Western Province) where the species will be introduced. The site conditions of these areas were investigated and described with its relationship to growth of the different plantation species planted and experiences were drawn and recommendations made for the introduction of these species to Kamusie and elsewhere in PNG with similar conditions.

Plantation forestry plays a central role in worldwide efforts to protect the environment and also an important economic and social role (Kanowski and Savill, 1992; Laarman and Sedjo 1992; Shepherd 1986). For example, New Zealand forest plantation provides 124,000 direct and indirect employments and supplies 1.1% of world's timber with export earnings of NZ$3.6 billion (McLaren 1996). Schultz (1999) also showed that loblolly pine plantation in the western United States provides 110,000 jobs and generates US$30 billion to the economy of the region. Environmentally, our growing forest plantation will absorb CO_2 for its growth, thus reducing the level of CO_2 in the air as indicated by McLaren (1996) that 1-ha of radiata pine plantation in New Zealand absorbs 24 tons of carbon annually or a total of 24 million tons of carbon annually from New Zealand forest alone. Similarly, Houghton and Skole (1990) estimated that 100-200 million hectares of developing or growing forests would absorb 1 billion tons of carbon.

Considering this, the initiative by RH (PNG) Group to embark on plantation forestry will continue to supplement economic growth while also providing social and environmental benefit as it has already demonstrated through its continued commitment to sustainable forest management in Papua New Guinea.

2.0. OBJECTIVES - REFORESTATION PROGRAMME

Rimbunan Hijau (PNG) Group is committed to sustainable forest management in Papua New Guinea and is moving onto reforestation purposely to:

1. sustain its resource base and operations especially the Kamusie Sawmill and Panakawa Veneer and Sawmill factories;
2. Resource/Forest replacement as required under the Forestry Act/Policy;
3. Corporate environmental responsibility including ecological and socio-economic benefits to the communities, province, nationally and regionally;
4. Promote its plans for Reforestation – Creating Partnership, Collaboration & Achieving our Common Vision & Missions by working together and replace forest resources.

3.0 EXISTING PLANTATIONS AND THEIR PURPOSES

Reforestation or rather plantation forestry in PNG began in the early 1960's but progress has been slow and to date only about 70,000 ha were planted. The current area of plantations in PNG, their size and purpose are shown in table 1.

Table 1: Existing plantations in PNG: Size, Species and purpose (Source: PNGFA 2003).

Location	**Species**	**Size (ha)**	**Purpose**
Bulolo/Wau	*Araucaria sp*	15000	Veneer & plywood production
Stetin Bay Lumber Co	Kamarere, Erima,Talis, Teak	10,000	Log export, sawn timber
Open Bay	Kamarere	~12000	Log Export, Sawn timber
Ulabo, Milne Bay	Talis, Kamarere,	2300	Sawn timber, log export
Whagi Swamp	Eucalyptus sp	2000	Drain swamp, supply fuel wood to tea factories
Kuriva	Teak	2000	Sawn timber
Kerevat	Teak	2500	Sawn Timber
Lapeigu & Fayantina	Pinus	8000	Sawn Timber, poles/posts
Gogol	*Acacia mangim*	20000	Chip mill-Pulp & paper production

These plantations provide certain socio-economic and environmental benefits to PNG. For example, the Bulolo/Wau, Gogol, SBLC, and Open Bay among others have contributed to the national and provincial economy while diversifying local economic activities and there is no doubt our proposed reforestation project will do the same.

4.0. GROWTH & PERFORMANCE: ULABO, SBLC & FRI TRIALS

With its initiative and intention to move into reforestation, the Company has conducted a simple study by selecting three sites with existing plantations including Ulabo, SBLC and research trial plantings by FRI in Lae to compare the growths and performances in relationship to climate and site conditions and make comparisons to Kamusie. This was done because whether a tree can survive a given physical environment depends on the physiological characteristics of the trees and the environment. The general climate and site conditions of these areas including rainfall, soil, and temperature and species composition were observed and described in relation to tree growth and performance and how similar species can perform in Kamusie and elsewhere with similar site conditions. The general observations and study is presented with a brief background on the plantations.

4.1 Ulabo Plantations, Milne Bay Province

Ulabo reforestation commenced in 1985 and covers over 2000-ha planted with Kamarere (*E.deglupta*), Talis (*Terminalia brassii*) as primary species including small plots of

Acacia, Teak and recently *E.pellita* (Kamarere) and *Dracontamelon dao* (Walnut) as secondary species. The first plantings of Kamarere and Talis are now 22 years old with average diameters over 50 cm (Turodawai-Pers.Comm).

At Ulabo, a standard spacing of 4 x 5 m is applied to almost all species of which the stems/ha is 500. Thinning and general plantation management at Ulabo is lacking due to constraints in funding (Turodawai-Pers.Comm). Thinning schedules for Ulabo plantation has not been specified but normally the first thinning to waste is done at age 5-years then second commercial thinning at age 20-years which was effectively practiced in SBLC. Thinning and effective management has dramatically increased high yield and returns e.g., final harvest of 248 stems of Kamarere at age 30-years in SBLC yielded 130 m^3 with an estimated financial return of US$6500 (if FOB sale at US$50/m^3) (Possani-unpublished). This however, demonstrated that effective plantation management influences high yield and financial returns (Figure 6). The growth and performances of the plantation species in Ulabo are estimated as shown in Table 2 (refer to footnotes for details).

Table 2: Mean annual increment (MAI) of height (m), dbh (cm) and volume of dominant trees and estimated volume growth per hectare per year of different species at Ulabo.

Species	**Age (Yrs)**	**MAI (**ht)*	**MAI** (dbh)*	***a*Vol (**m^3)‡	**Vol** (m^3/ha) (*a* x 500sph)	**MAI** (Vol-m^3/ha/yr)
Kamarere (Site B)	17 (1990)	21	49	3.96	1980	116.47
Talis	17 (1990)	18	43	2.61	1305	76.76
Kamarere (Site A)	17 (1990)	20	34	1.82	910	53.53
Teak (Site A	17 (1990)	11	33	0.94	470	27.65
Acacia	22 (1985)	15	42	2.08	1040	47.27
Teak (Site B	22 (1985)	15	35	1.44	720	32.72
Walnut	5 (2002)	6	24	0.27	135	27

* Mean height (merchantable), diameter and volume of dominant trees (5 trees each)

‡ Formula for Volume calculation $V=0.7854D^2L$ where V volume in cubic meter; D diameter in meter; L length or height in meter (Volume is calculated at merchantable height). Volume of individual tree (aVol) is multiplied by 500 sph to obtain vol/ha then divided by age to obtain vol/ha/year. The vol/ha/yr can be used to estimate volume of stand at any given age. This has been used to calculate volume at different ages and is projected in graph. Similar method is applied to Lae and SBLC.

Although there are differences in growth, both Talis and Kamarere can produce up to 1000 m^3/ha in 15-20 years compared to other species at Ulabo (Table 2 & Figure 1). The 1000m^3/ha is only an assumption based on the measurements of the 5-dominant trees in the plantation but true growth and volume production does not happen as stated in plantations given thinning, competition and stagnation which reduce the number of trees per hectare and ultimately its volume.

4.1.1 Site Conditions & Tree Growth-Ulabo

Site conditions and climate can have marked influence on growth and performance of trees even within the same ecological region or microsite. This is clearly demonstrated in Ulabo for Kamarere on site A & B where A (good site) produces over 3000m^3/ha at age 30 (assuming all trees are uniformly grown without competition/stagnation-which is often the case in nature) while the same species at the same age produces under 1000m^3/ha in about less than half a kilometer away. A similar situation was also observed in Teak on site A (Table 2 & Figure 1), planted on compacted soil where growth was poor presumably as a result of poor root penetration and lack of soil moisture content which lead to physiological stress during dry period. The physiological stress may have limit leaf life thereby reducing photosynthetic capacity resulting slower growth rate and volume production compared to site B (Figure 1). While it may be easier to provide this explanation, the growth differences can also be attributed to the manipulation of silvicultural practices e.g., thinning which may eventually increase volume growth but this has not been effectively practiced at Ulabo (Turodawai-Pers.Comm).

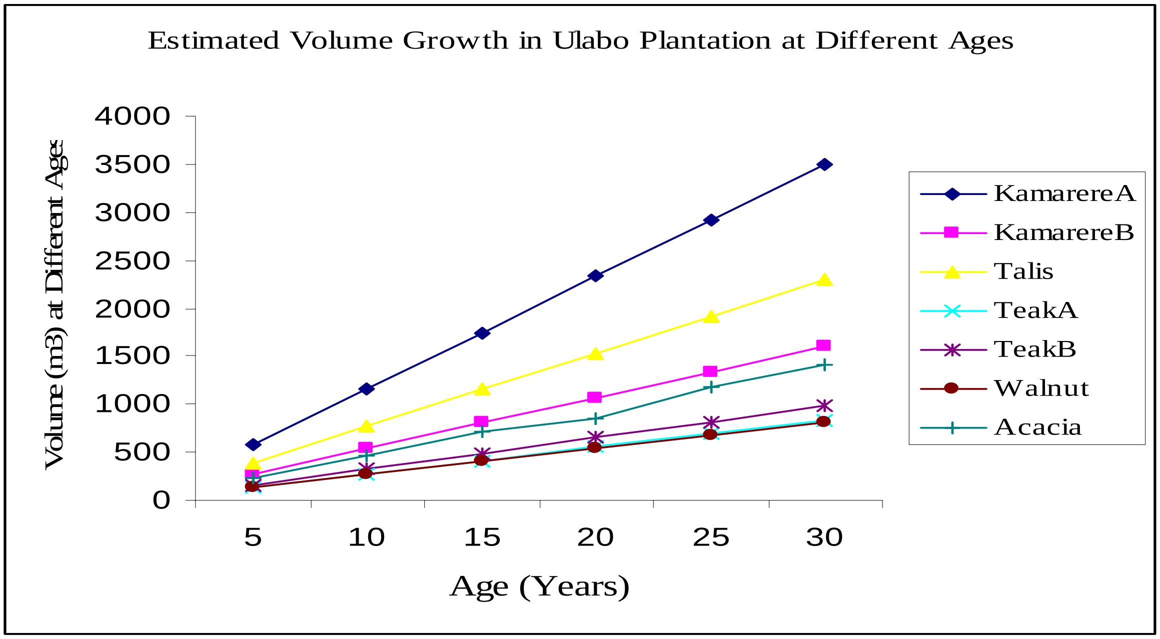


Figure 1: Volume growth per hectare of species at different ages at the Ulabo Plantation

Note that these figures are estimates and MAI changes with time which reveals the effect of site conditions and stand treatment on stand growth. The effect can be quantified indirectly by analyzing yield tables but yield tables are not available for most species in PNG. Figure 10 explains that trees can be cut when it reaches its maximum sustained yield because that is where high economic return can be achieved Such values however, are only indicative but showing effect of an economic option on dendrometric parameter such as the available timber volume at each or any given age of harvest.

While silvicultural manipulation can be done to increase timber yield, Talis and Kamarere adapted well on the site with Talis preferring fresh water swamps and waterlogged areas and Kamarere prefers deep, sandy to clay loam soils.

Figure 2A: Natural stands (Open Bay) **2B:** Natural regeneration of Kamarere, Open Bay
*(*Photo courtesy of Gedissa Jeffrey, FRI, Lae)*

Generally, the predominantly sandy to sandy loam soil with 1500-3000 mm annual rainfall and temperatures at 28-32^{o}C appears to be a suitable condition for Kamarere and with similar climate but swampy condition is extremely suitable for Talis in Ulabo.
On such sites and with efficient plantation management, Kamarere can perform exceptionally well expressing clear boles as seen in this Gedissa Jeffrey photo (Figure 2A) and management can be done in ways that promote natural regeneration (Photo 2B) which will substantially reduce establishment costs.

Further, on this site condition and climate, Kamarere and Talis can reach 50 cm dbh and produces over 1000 m^3 of timbers per hectare at age 15-20 years. This however depicts that rotation age for both species may fall within that age range depending on site but for the case of Kamusie, it is expected to be shorter for both species given its site conditions. Both Kamarere and Talis are fast growing and the factors that influence fast growth rates are not known but considered to be associated with its genetic, environment and physiology.

4.2 FRI Trials, Lae

The Planted Forest Programme of the PNG Forest Research Institute (FRI) has done some remarkable research on indigenous species domestication for industrial plantation development. Many species trials were established and certain information were collected. Among numerous trials with several tree species in many parts of the country, Taun, Kamarere, and Talis stand out as potential for industrial plantation species (Paul and Jeffrey-Pers.Comm).

According to Jeffery (unpublished) Kamarere can attain MAI of 2-3 m in height and 2-3 cm in diameter in the first 10 years. This however, conforms to growth rates of Kamarere at SBLC and Ulabo where it grew at almost 2 m in height and 2 cm in diameter annually. Recently, Kamarere is considered by PNGFA as its priority species on its list of species for plantation (Jeffrey-Pers.Comm). Other species where extensive researches have been undertaken are presented in table 3. Most trial plantings by FRI use 3 x 3 m spacing

(1111 sph) which on plantation standard is too clustered and may incur high management costs but for the purpose of research is acceptable.

Table 3: Growth rates of Species at FRI Trials in Lae

Species	Age (Years)	Height (m) (Merchantable)	Diameter (cm)	Volume (m^3)	Vol/ha	Vol/ha/yr
Kamarere	10 (1997)	17	35	1.63	1087	108.7
E.pellita	13 (1994)	18	24	0.81	540.27	41.56
Talis	33 (1974)	20	51	4.08	2040	61.82
Taun	10 (1997)	11	26	0.584 (1111)	648.8	64.88
Rosewood	10 (1997)	6	18	0.153 (1111)	161	16.1
Kwila	10 (1997)	6	17.5	0.144 (1111)	160.3	16.03
Black bean	NA	NA	NA	NA	NA	NA
Calophyllum	NA	NA	NA	NA	NA	NA

The growth data for Black bean (*Castanosperma australe*) and *Calophyllum* were not available but observations indicated that both species had fast to moderate growth.

4.2.1 Site Conditions & Tree Growth –FRI, Lae

Influence of site and climate is common in all sites but Lae appears to demonstrate similar ecological niche to those of Kamusie. Lae with high rainfall exceeding 4000 mm annually, humid with temperature range at 28-32^oC and mostly deep, clay loam, fertile soil with high soil moisture content all year round appears to be responsible for rapid plant growth. Such similar climatic condition is observed in Kamusie and it is highly likely that performance of trees in Kamusie may be related to the growth rates of similar species in Lae.

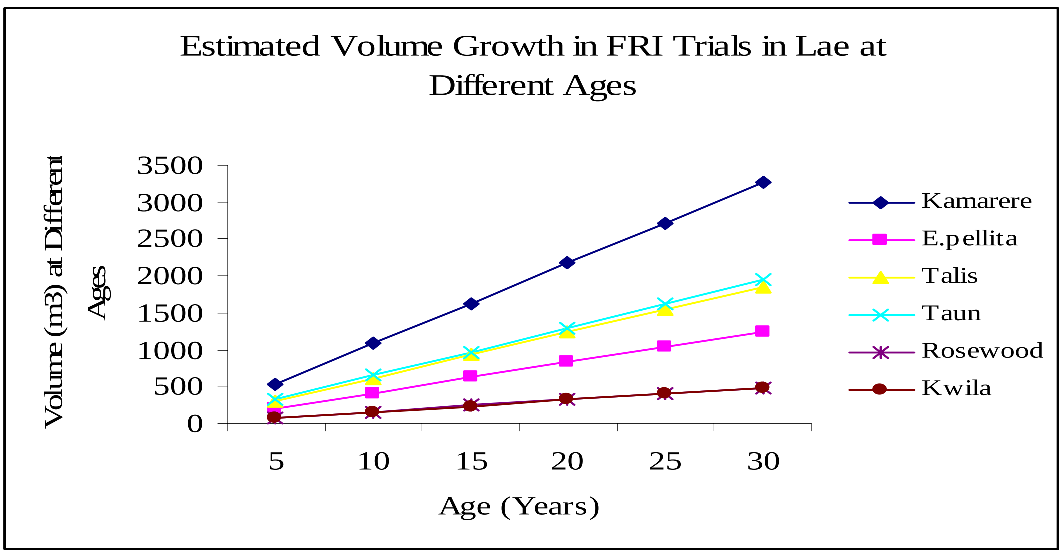


Figure 3: Estimated volume production/ha at different age for FRI Trials in Lae & Markham Valley (*E.pellita*)

Kamarere is a leading fast growing tree almost everywhere compared to other species but Taun, an indigenous high valued timber showed a remarkable growth rate producing over 1000m^3/ha in less than 20 years. The growth of Taun appears to be equivalent to those of Talis and Kamarere and can be a suitable plantation species while the famous Rosewood and Kwila grew at almost the same slow rate (Figure 3 & Table 3).

Similarly *E. pellita* a related species to *E. deglupta*, demonstrates fast growth and thrives well on grassland with low rainfall, resilient to fire, self prunes, expressing clear boles of 20 m, and has the ability to coppice successfully of which successive rotations can be purely managed from coppice. The tree grew up to 9-12 meters in height at a trial in the Markham Valley in just 2 years. That site has an annual rainfall of 1500-2000 mm and temperature at 30-34^{o}C with well drained, weakly acid to neutral soil (Paul-unpublished). The well drained, aerated and mostly sandy to sandy loam soil appears to be shallow and dries out rapidly. The lack of soil moisture condition may cause physiological shocks in young trees during drought periods and also reduces leaf life that ultimately slows photosynthetic activity leading to reduction in tree growth.

On the same site, Paul (unpublished) did an excellent research that show *E.pellita* producing 1682.3m^3/ha at a spacing of 5x3 m (667 sph) but with an application of 20.79 kg of NPK fertilizer, total volume production has dramatically increased to 2291m^3/ha (total volume) over 15 months in that 7 year old trial plantation. Such applied research and management can lead to substantial gains in monetary value for plantation products.

4.3 SBLC Plantation, Kimbe

Stetin Bay Lumber Company (SBLC) ventured into reforestation since 1984 to sustain its resource base after a 62 ha trial plantation in 1976 and 1977. Today SBLC has over 10,000 ha of plantation of which 2944 ha is owned by the Company while the remaining 7100 ha is state owned. The company manages the reforestation programme including state owned plantation.

SBLC commence harvesting from the plantation in 1999 for export and milling at its Buluma sawmills. The company since 1999 to end 2006 harvested over 208,000m^3 from 2918 ha of the plantation while at the same time replanting. This demonstrates the high yield of timber that can be produced from plantations compared to natural forest which are sporadic. The harvested timbers are mostly Kamarere (Figure 4).

Table 4: Growth Rates of plantation species at SBLC

Species	Age (Years)	MAI(ht m)	MAI (cm-dbh)	Volume (m^3)	Vol/ha	Volume (m^3/ha/yr)
Kamarere	15	20	47	3.47 (625)	2168.75	144.58
Erima	15	25	49	4.71 (625)	2943.75	196.25
Teak	10	9	20	0.28 (625)	175	17.5
Talis	10	21	21	0.52 (625)	325	32.5
Gmelina arborea	NA	NA	NA	NA	NA	NA
Silver quandong	NA	NA	NA	NA	NA	NA
Acacia mangium	NA	NA	NA	NA	NA	NA
A.auriculiformis	NA	NA	NA	NA	NA	NA
Black bean	NA	NA	NA	NA	NA	NA

The primary plantation species at SBLC is Kamarere along with Erima and Talis and more recently Teak but the focus appears to be on Kamarere (Table 4). Kamarere performs extremely well in SBLC and the growth closely resemble with Erima while other species grew at a steady but slower rate. Erima produced almost 3000m^3/ha at age 15 years while Kamarere produce over 2000 m^3/ha at the same age (Figure 5 and Table 4).

Figure 4: A. Log piles at SBLC log pond (Kamarere) **B.** Logging from Plantation- SBLC
**Photo courtesy of Gedisa Jeffrey, FRI Lae.*

4.3.1 Site Conditions and Tree Growth-SBLC

It was surprising to note that Talis grew at a steady but slower rate compared to other sites (see Tables & Figures presented for different sites). This was presumably attributed to site conditions as they were not planted in fresh water swamps or waterlogged areas as in Lae and Ulabo.

In any case, site productivity of SBLC appears to be high as expressed on the growths of Kamarere at different sites (Figure 6). Further, the deep, sandy loam soil with high rainfall appears to be a perfect condition for Kamarere and Erima (Figure 5) and perhaps Teak but not Talis if maximum growth is to be attained in short rotations.

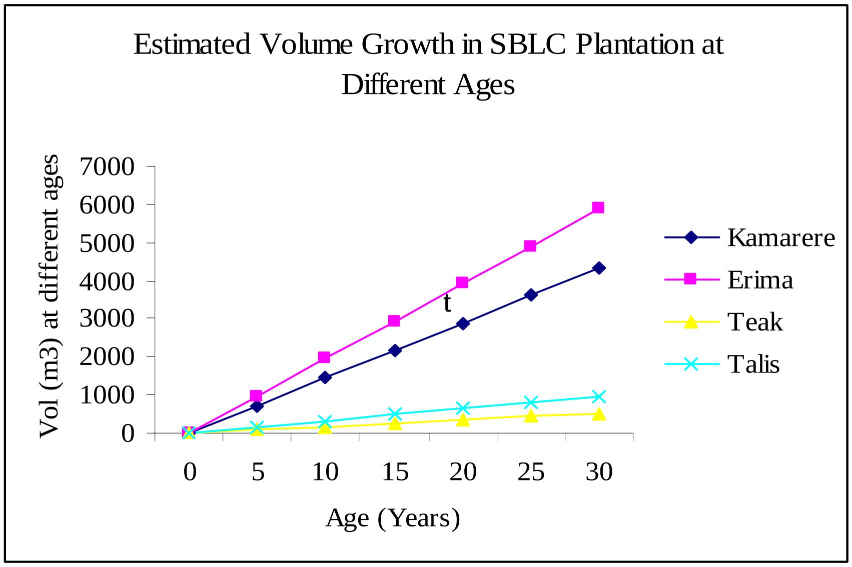


Figure 5: Estimated Volume (m3/ha) at different age for plantation species at SBLC.

An interesting feature to note is the excellent ability of Teak to coppice efficiently from 1-year old stumps after harvest at SBLC. The 1-year old coppice has mean height of 4 m and 3 cm diameter. This is a remarkable growth and survival ratio has also been high. Successive Teak plantations or rather next rotations can purely be managed from coppice which reduces establishment costs and high monetary returns.

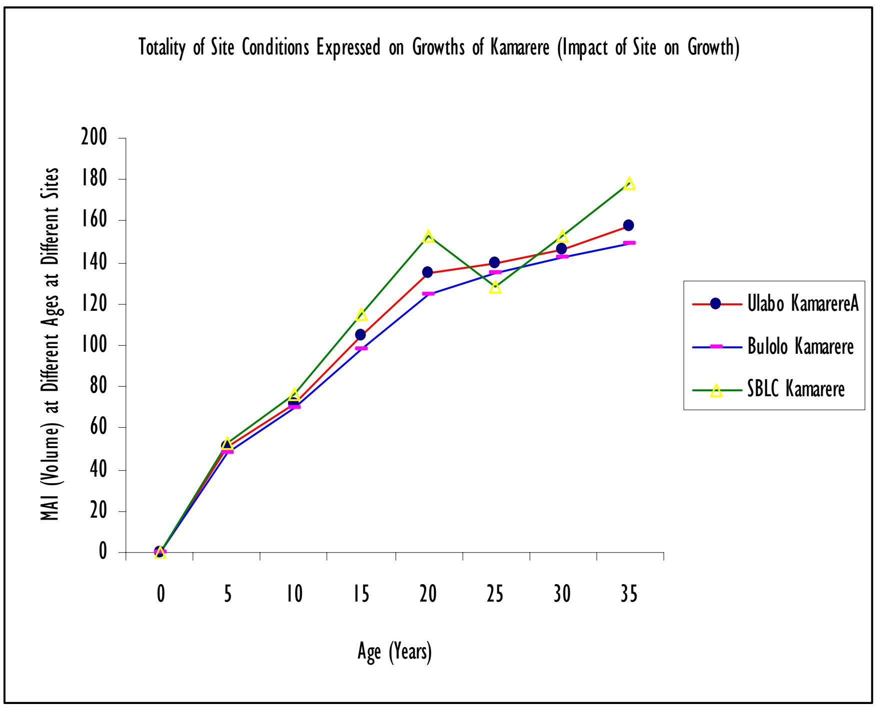
Talis, though is fast growing has not gained adequate volume increment over time in SBLC (Figure 5) compared to other species and this clearly showed that Talis is best for waterlogged and swamp conditions.

5.0. COMPARISON: SITE, CLIMATE, TREE GROWTH AND ITS RELATIONSHIP TO KAMUSIE CONIDTION AND ELSEWHERE

Kamusie like any other site is controlled by several factors including solar energy, water, carbon dioxide and various chemical nutrients. Sites can be categorized by the absence or presence of one or more such factors. These factors influence tree growth and performance and it is impractical to know the exact physical and chemical conditions of the site but a general understanding of the characteristics of plant growth and behavior in relationship to site is crucial to the introduction of species to site. Viewing this, Table 9 compares and contrasts site conditions based on climate, soil and tree characteristics as prerequisites for its introduction to Kamusie and elsewhere.

Each site presents its own peculiar climatic regimes but the three sites visited does not show distinct variations in climatic differences. The rainfall and temperature appears to be similar but physical soils conditions differ at all sites and support certain plant growth. For example, the SBLC area has an average annual rainfall between 3500-4000 mm, and temperature at a maximum of 30^{o}C with soil mostly sandy loam and deep with moderate soil moisture content but water deficit appears to be minimal. The temperature and rainfall in Lae is similar to SBLC but soil physical condition differs where Lae is mostly clay loam, deep and fertile with very high soil moisture content. Similarly, in Ulabo temperature is similar to those of Lae, SBLC and even Kamusie but rainfall and soil physical conditions differ. Ulabo has annual rainfall of 1500-3000 mm with sandy to sandy loam soils that appears to lack soil moisture content. In comparison, the Lae condition appears to be closely related to Kamusie.

Comparing these site conditions with Kamusie, Kamusie appears to be a perfect site for Kamarere, Talis, Taun and perhaps a host of other species. Kamusie with waterlogged and clay soil conditions and abundant rainfall exceeding 4000 mm, both Kamarere and Talis will thrive well there. Further, the relatively high soil moisture content in Kamusie will minimize plant-water stress and maximize photosynthesis thereby accelerating growth. This has been demonstrated in the logged over forest where regeneration has been successful and the forest have been reconstituted more rapidly compared to other areas. Further, Talis and Kamarere appear to have root elasticity that can penetrate through areas with poor aeration and performs better as demonstrated in the Whagi Swamp plantation for Kamarere and in Lae and Ulabo for Talis. This physiological feature, however provide us with confidence that both species can perform better at Kamusie given the waterlogged and clay soil condition and abundant rainfall with humid climate. Interestingly, Kamusie though experienced high flood from its nearest Bamu and Purari Rivers including high water table it does not damage tree growth.



Site productivity is expressed on tree growth but the growth on the 3 sites appears to be similar although slight variations were depicted. The growth does not show much difference accept SBLC being slightly higher which is obviously attributed to their effective plantation management. In an intensively managed plantation, marked differences can be observed in volume production as in the case of SBLC after its second commercial thinning. Soon after thinning, growth is reduced but sufficient growing space is created where remaining trees maximize its growth and volume production in subsequent years through to final harvest age.

Figure 6: Impact of Site Conditions and Management on Volume growth of Kamarere at different age at different sites.

Considering the site conditions, Kamarere, Talis and Taun can be planted as principle species in Kamusie and a host of other species including Teak, *E.pellita*, Walnut, Erima as secondary species as a trial. This approach will however maintain soil productivity as monoculture plantation will exhaust site nutrient and overtime productivity declines.

Alternatively, the secondary species will also be our next choice of species given their performance on the site.

The growth comparisons of the major plantation species at the 3 sites (Tables1-3-5 and Figures1-3-5) showed that Kamarere is a clear leader followed closely with Erima, Talis and surprisingly Taun. Taun cannot be ignored but is in the same group of fast growing species such as Talis, Erima and Kamarere.

6.0 ESTABLISHMENT & MANAGEMENT

The establishment and management practices differ from the different areas depending on end uses, type of species, and land use practices. The cost of establishment from nursery to field planting also varies and depends on the size of the area, accessibility, and manpower among others.

6.1. Nursery

Details on nurseries have been discussed in the previous report on the Wawo-Guavi Pilot Project Report. The nursery size and capacity depends on the reforestation programme and the size of the area to be planted. The general nursery practices are uniform however different species require different treatments at the nursery.

Figure 7: Kamarere seedlings at the nursery-Open Bay (2.5 months old). (Photo courtesy of Gedisa Jeffrey, FRI)

According to Henry Turawdawai (Project Supervisor Ulabo), Kamarere takes about 3-months from nursery to out planting in Ulabo but at SBLC nursery, it takes about 6-months from sowing in nursery to outplanting while Jeffery (Scientific Officer-FRI), it takes about 4-months in the nursery before outplanting. Jeffery (FRI) further claimed that wildings of Kamarere takes only 1-month at the nursery before they are outplanted which is much more economical as it reduces costs of nursery care and management including establishment. The details on the nursery practices of major timbers of PNG can be found in Yelu.W.D (2000), “Nursery Practices of Common Timbers of Papua New Guinea”, PNGFRI Bulletin No. 23.

6.2. Establishment & Maintenance

The establishment and management in any reforestation are almost uniform but vary on the end uses of the plantation and site conditions. However, the general procedures in plantation establishment and management include:
-Boundary/Compartment Survey
-Site preparation (under-brushing, felling, branch cutting and picketing)
-Planting
-Tending and maintenance
-Thinning

The costs of plantation also varies and those applied at the Ulabo reforestation project is based on K8.00 per man-day for all its operations from seed to nursery, site preparation and plantation care and management. The costs will vary depending on design and management, size of plantation, and condition of the site. The rate used in Ulabo is perhaps a standard rate applied across all reforestation activities undertaken by PNG Forest Authority.

Table 5: Details of activities required for plantation establishment and management at Ulabo

Activity	Costs	Remark
Site Preparation: This includes boundary survey; roading; under clearing; picketing; planting; survival count; refilling etc	K633	Site preparation will depend on the nature and condition of the site of which costs will vary.
Maintenance: Tending and thinning including other pests and diseases management.	K368	Tending can be either manual or chemical & again cost varies. Thinning to waste at age 5 and commercial thinning at age 15-20 (no details on thinning & stock density)
Nursery: Including soil tubing, bed transfer, fertilization, weeding, seed sowing etc	K38.20	
Total	**K1039.2**	

* Note that Talis and Kamarere takes about 3-months to reach planting size and it is advisable that while raising planting stock, site preparation must also be undertaken.

SBLC uses the contract system where contractors (especially landowners or settlers who reside near the project site) were engaged on a 3-year contract. Over the 3-year period, they do site preparation, planting, tending and general care and maintenance until the tree reach 3 years. The plantation or tree at age 3 years is already big and maintenance is reduced. The contract team is paid after each activity is completed and once an inspection is made by a supervisor who certifies that the work has been satisfactorily completed. And where survival rates of the plantation were high (85% or more) after 3 years, the contractors were paid bonuses. FRI however uses K10/man/day for trial establishment but such rate is not practical in large scale reforestation projects.

6.3 Stand Density

The standard spacing applied at SBLC is 4 X 4 m for most of its plantation species while in Ulabo is at 4 x 5 m spacing for both Kamarere and Talis and FRI uses 3 m x 3 m for its *E.pellita* but other species vary. Ulabo did not carry out any thinning due to constraints in funding but SBLC does thinning to waste at age 5 and a second commercial thinning at age 20-years where 248 stems were left for final harvest at age 30. With this final stocking of Kamarere and at average volume growth of 0.017m^3 per individual tree per year, the final harvest volume at year 30 is expected to be around 126.48 m^3 and if the export price is at US$50/$m^3$, the plantation's financial return is estimated to be US$6324/ha (Possani-Unpublished).

6.4 Pests & Diseases

Pests and diseases can cause substantial setbacks in plantation and can wipe out the plantation which may lead to change of species. A good knowledge of the pests and diseases is necessary to protect plantation but there is no cases of serious plantation pests and disease encountered at both the SBLC and Ulabo plantations. However, beetle attack and leaf defoliation are reported for Open Bay and also in SBLC and Ulabo but did not appeared to be serious damaging the plantation.

Figure 8: Beetle attack on young Kamarere

Plantation pests and diseases have been reported in plantations in PNG such as the Termite attacks in the Bulolo/Wau Pine plantation that almost wipes the entire plantation. For nurseries in PNG and elsewhere the common pests and disease problem is damping off of young seedlings.

The leaf defoliation seen in this photo is mainly on young leaves. As leaves grew older, it is hardened and cannot be defoliated but it reduces the photosynthetic capacity of the tree which may

Figure 9: Leaf defoliation (Open Bay) *(All Photos courtesy of Gedisa Jeffery, FRI, Lae)*

Damping-off is caused by a wide variety of parasitic fungi that infest organic debris. This fungi develops rapidly especially in moist shaded or closely spaced seedling beds and has been reported in Ulabo, SBLC and at FRI nursery. The best way to overcome this problem is to sterilize the soil before tubing and may be done with fumigants. Soil sterilization eliminates the soil fungi that live in symbiosis with tree roots.

7.0 SUMMARY ON POTENTIAL PLANTATION SPECIES

Selecting the right species for the right site is not easy and several factors are often considered. Table 6 presents some of these factors and further compares the climatic condition and recommends certain species to Kamusie.

Table 6: Summary on Species: Matrix to aid species selection for pilot reforestation project in Kamusie and elsewhere in Papua New Guinea.

Talis	High economic value; fast growth reaching over 50 cm dbh &1000 m3/ha in 20-25 years; grows well in fresh water swamps and waterlogged & clay soil conditions; abundant seeds available; ease of nursery handling; ecology & silviculture known	Best for Kamusie & highly recommended
Teak	High value timber; can fetch up to US$200-400/m3 (ITTO 2003/2004); moderate growth rate reaching 35-40 cm dbh in 19-21 years; prefers sandy loam, deep & well drained soil of moderate fertility and does not stand waterlogged conditions; ecology & silviculture widely known; seed and cuttings can be used; excellent coppice ability-second rotations and beyond will be on coppice-reduce establishment & management costs & high return.	May perform well on higher ground- not in waterlogged & swamp sites
Walnut	High value timber with moderate growth rates reaching over 50 cm in 35-40 years; abundant seed but slow germination; prefers deep, clay-sandy loam soils with high rainfall sites; never planted in plantation; silviculture & ecology unknown but pilot trials at Ulabo & Lae shows promise.	Can be planted as secondary sp for observation & research.

E.pellita Kamarere	High value timber, relative to E.deglupta but more fast growth compared to E.deglupta; grows on any site; resilient to fire; excellent coppice like Teak & second rotations and beyond mainly through coppice; silviculture & ecology known; abundant seed available through NTSC, Bulolo.	Suitable for Kamusie perhaps as secondary species.
Acacias	Fast growth with rotation ages of 8-10 years for pulp and paper production; famous plantation species in the tropics; silviculture & ecology widely known and abundant seed available; prefers deep, clay-sandy loam soils.	May grow well but what about the end use?
Erima	Low economic value, fast growth, pioneer species so performs well on any site accept in swamp and waterlogged conditions, short rotation plantation crop and produces over 3000m3/ha in 15-18 years	Good but what about market and enduse?
Black bean	Not much information collected but the species is endemic to Talasea and the West New Britain area and may be considered for Asengseng	
Kwila	High economic value, slow growth with long rotation but seed technology aspects and nursery practices known; for clear bole may require high stock density at initial planting and thin in later stages. Growth also picks up when tree reaches 4-5 years presumably as a result of active photosynthesis.	May grow but not in our list of criteria as plantation species
Rosewood	High economic value, slow growth and long rotation with multiple leaders and may require intensive management in the initial stages of growth; seed technology and nursery practices known but growth behavior similar to Kwila.	May grow but not in our list of criteria as plantation species

8.0 FINANCIAL ESTIMATION FROM REFORESTATION

Reforestation can be undertaken for various reasons e.g., watershed management; landscape and biodiversity restoration; carbon sequestration; sedimentation control; timber production or combination of one or more of these uses. The financial return from reforestation also vary with the kind of service or product the reforestation programme is intended to produce but for the case of timber, available growth and yield tables can be used to predict financial returns or the mean annual increment (MAI) can be used to estimate financial return. For Example, the MAI of an individual Kamarere tree at SBLC is 0.017m^3/year and the final harvest is normally 300 sph at age 30-years. By age 30-years, each individual tree will produce about 0.51 m^3 (0.017m^3*30 years) and about 153 m^3/ha (0.51m^3*300sph). If the log export price for Kamarere is at \$50/m^3 (FOB) then the estimate financial return would be \$7650 (153m^3 * \$50) –Reforestation, Harvesting and Milling/Export Costs = Net Profit.

Forest Plantation Managers can also manipulate silviculture to maximize production and financial returns as demonstrated by the Fautsmann theory (Figure 10). The Faustmann theory however is based on ‘maximum sustainable yield’ where tree is cut/harvested when average growth i.e., MAI (Vol. m^3/ha) at any given age is highest. The Faustmann rotation will be used in subsequent rotations of the proposed reforestation program if it appears to be a profitable option. The management rotation age can be compared with

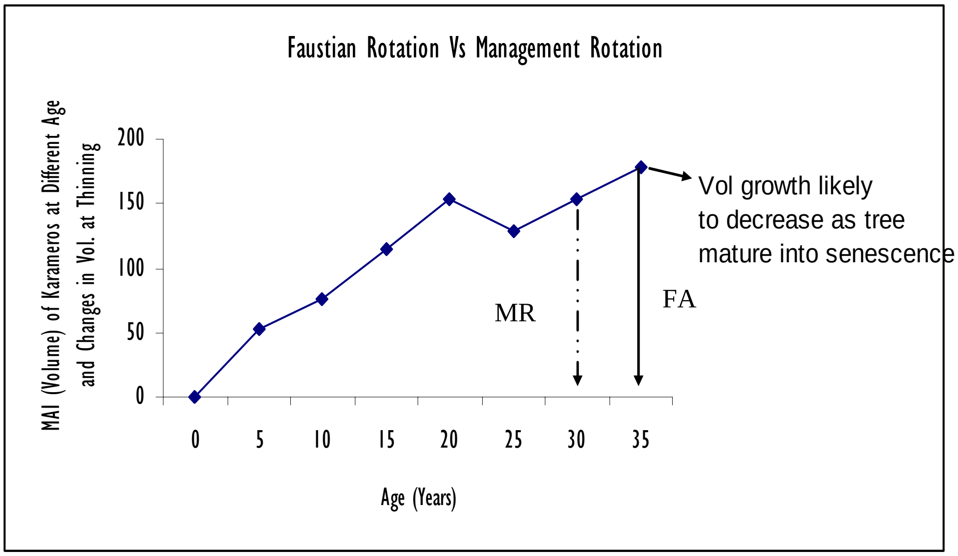


Figure 10: MAI (Volume) production indicating Faustmann rotation (FA) and management rotation (MR) in Kamarere at SBLC at different age and thinning.

Faustmann rotation age where cost-benefit-analysis will be made and profitability will be evaluated to decide on a suitable rotation age. For example, the Kamarere plantation at SBLC has management cycle of 30-years but if Faustmann rotation is to be applied then trees will be cut at age 35-years old (Figure 10). Further, Fautsmann rotation looks at the optimal condition where the 'net benefit' of cutting trees is equivalent to the 'net benefit' of delaying cutting tree.

9.0 REFORESTATION & FORESTRY IN SUSTAINABLE DEVELOPMENT

The word "sustainable development" is one of the most used terms but has no precise definition. The term has gained widespread use among policy makers and scientists alike. Sustainable development in the context of forestry is "sustained yield management" where continuous supply of timber can be obtained from a given forest while still maintaining the ecological system where social and environmental functions continue. In forestry, "sustained yield" fits the biophysical definition of sustainability though the word "sustainability" is used across social, economic and environmental disciplines with different definitions and context (Laarman and Sedjo 1992). The concept of 'sustained yield' forest management in tropical forest is more challenging given its diversity; lack of understanding on the ecology and forest dynamics to formulate any appropriate sivicultural system. As such, there is uncertainty in total recovery of a forest after it is logged. Considering this, alternative ways such as reforestation must parallel with forest harvesting to offset the loss of natural forest to continue provide environmental, social and economic service aiding sustainable development.

Reforestation and Forestry from the Environment dimension of sustainable development plays a vital role in pushing growth in the socio-economic dimension and RH has driven *this sustanomics triangle (Figure 11) to action in PNG since its inception 20-years ago.* Further, RH is committed to sustainable forest management in PNG by linking ecological-social-economic interfaces aiding sustainable development and the kind of socio-economic services it provides speak for it.

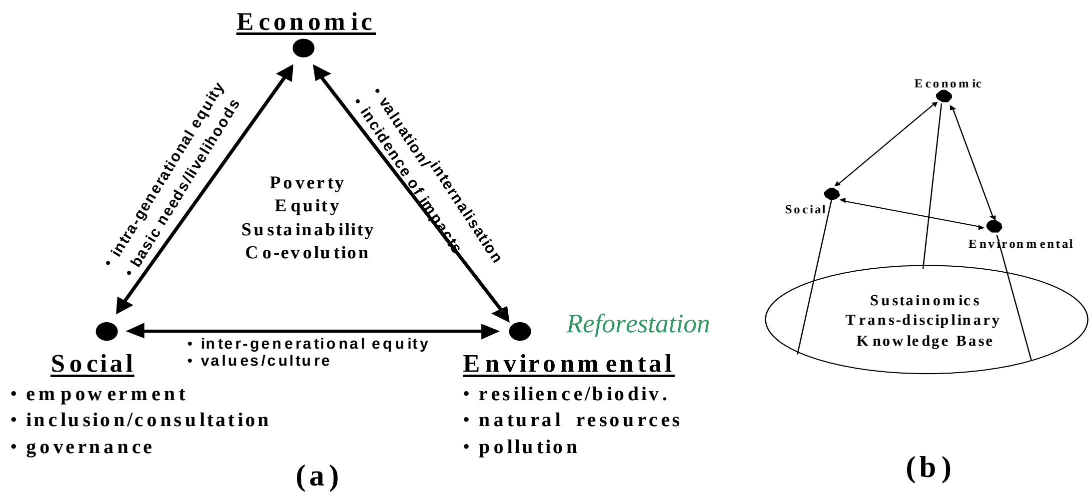


Figure 1 (a). Elements of sustainable development
1 (b). Sustainable development triangle supported by the sustainomics framework.
Source: adapted from Munasinghe [3,4]

Source: Munasinghe (2000)

Figure 11: Sustainomics Triangle Depicting Reforestation on the Environmental Dimension of Sustainable Development that benefits Social and Economic Dimensions aiding Sustainable Development. 11(a) Elements of sustainable development 11(b) Sustainable development triangle supported by sustainomics framework.

Further, humanity has witnessed that forest has played a major role in the economic development (Laarman and Sedjo, 1992; Sedjo, 1983; Klemperer, 2003; Sharma, 1992; Evans, 1992) of both developed and developing countries. The forests has direct link with environment and plays crucial roles e.g., carbon sequestration (McClaren, 1996; Robinson et al. 1998; Woodwell, 1992; Houghton and Skole, 1990; Laarman and Sedjo, 1992; Kanowski, 1997; Cannel, 1999), stabilize climate (Sharma, 1992; Woodwell, 1992; Evans, 1992), influence precipitation and regulate stream flow (Sharma, 1992) among others. On the social dimension, people have long been associated with forest for their welfare and development needs. In all, forests play significant role in all dimensions of sustainable development and benefited people.

Similarly PNG's forest resource plays an important economic, social and environmental role in the country's development of which RH (PNG) Group is a major player that brings tangible socio-economic benefits to areas where government services never existed. Through the reforestation efforts by the company, similar benefits will continue to be derived which is all connected to sustainable development as demonstrated in Figure 11 and in Table 7 with further discussions in the preceding pages.

9.1 Economic Benefits

Since RH commence operations in PNG it expanded rapidly and is now PNG's largest forest harvesting and exporting company and contributed K77.1 million a year to the country's economy and employs over 5000 people (ITS Global, 2007). Further, the company has built major infrastructures and provides social services to rural areas where government services were non existent. The company is therefore filling a major economic gap and it will continue to provide these essential social and economic developments even through their initiative on the reforestation programme.

PNG's forest plays an important role in the nation's economy - forests exports contribute US$300 million (Mathrani 2003) annually and remains the second major revenue earner to the country. In order for PNG's forests to continue supplement economic growth, forest harvesting must parallel replanting through efforts such as reforestation currently initiated by the company. Where the efficiency of service and products from the natural forests cannot be maintained (where forest are lost), plantation forestry is widely considered as an alternative (Kanowski, 1997; Sedjo, 1983; Laarman and Sedjo, 1992; Kemperer, 2003) to supplement economic growth and provides social and ecological functions. For example, New Zealand forest plantation provides 124000 direct and indirect employments and supplies 1.1% of world's timber with export earnings of NZ$3.6 billion (McLaren 1996).

Further, timbers grown in plantations and intensively managed will fetch high economic return (revenue), as they will produce uniform size logs of equal value per unit area than natural forests. The uniform end product from plantation is however considered as a risk in investments in plantations (Shepherd, 1986) in the event of market change but the Company has well set-up processing plants and established marketing network which can meet market changes. Further, the reforestation projects will be closer to the existing processing plants, thus a compromise balancing transport costs of the raw material against those of the product.

9.2 Environmental Benefits

Reforestation can play certain roles in restoring biodiversity, regulate stream flow, sequester carbon, and reduce surface runoff (erosion) including other social and environmental functions. It is anticipated that the reforestation initiative undertaken by the company will play a part in biodiversity restorations and mitigating green house effect as demonstrated by plantations elsewhere showing potential as a source of carbon sink. For example, biodiversity in old pine plantations in New Zealand is comparable to natural podocarp forests (McLaren 1996). McLaren further reported 625 pairs of native bird species per 100-ha of pine plantation, including 270 vascular plants of which 200 were indigenous. Similarly, a high altitude species trial plantation established by the author in Whagi Swamp, Western Highlands Province had natural regeneration from seeds of planted trees; forest birds and possums were returning to the site and the area was almost reconstituted with forest of a typical high altitude form. The proposed reforestation programme by RH will also provide similar function.

Plantation appears to be a good source of ‘carbon sink’ though they were often viewed as source of low ‘carbon sinks.’ As Laarman and Sedjo (1992) rightly stated, “just as climate affects forest, forests are able to affect climate - if deforestation puts carbon dioxide in the atmosphere, reforestation takes it out”. McLaren further showed that 1-ha of radiata pine plantation in New Zealand absorbs 24 tons of carbon annually or a total of 24 million tons of carbon annually from New Zealand forest alone. Similarly, Houghton and Skole (1990) estimated that 100-200 million hectares of developing or growing forests would absorb 1 billion tons of carbon. This further indicates that a growing forest plantation will absorb more CO_2 for its growth, thus reducing the level of CO_2 in the air.

The Company as part of its Corporate Environmental responsibility will commission an independent 3rd Party to Study Silvicultural Investments in Carbon Accounting/Abatement and further through its Reforestation & Forest Management practices will calculate forest carbon contributions to the regional & global carbon cycle. This however will also benefit Papua New Guinea in its efforts for carbon trading because in order to buy or sell a good or service, it needs to be quantified. And to quantify, we need to understand how to measure forest ecosystem carbon dynamic & carbon budgets which are certainly essential to the development of carbon markets and the company is willing to undertake this as a pilot project.

9.3 Social Benefits

The social benefits of plantation forestry are numerous, e.g., fuelwood (Evans 1992; Kanowski 1997; Sedjo 1983; Leach and Mearns, 1988), agroforestry and taungya systems (Evans 1992; Dewees and Scherr, 1996). The company intends to incorporate some of these into the project to satisfy social needs of the people while also providing ecological and economical benefits further improving their livelihood.

The reforestation project will continue to benefit people by diversifying the rural economy and provide employment among others (Table 7).

Table 7. Matrix of benefits likely to be derived from the proposed reforestation projects

Social	**Ecological**	**Economical**
Employment	Carbon sequestration	Timber Production
Recreation	Wildlife	Carbon trade
Taungya systems	Aesthetic	Diversification of local economy
Fuelwood	Landscape & Biodiversity Restoration	Recreation, Tourism, Harvesting & Marketing of Minor Forest Products etc,

The project will involve all stakeholders including provincial and local governments and local people to participate in project activities and incorporate the social needs of the people, e.g., introducing ‘taungya system’ where the landless and people at the vicinity of the project site will be allowed to plant food crops in the plantation. This will minimize the cost of plantation establishment, as the people will take care of the planted trees as they care for their food crops. The project will also encourage equal gender participation in all project activities, e.g., women and children will be contracted to do tree planting and tending while men will be engaged in tougher activities such as thinning and pruning.

9.4 Policy

Policies relating to forestry resources and its use and management has been widely studied and used in many countries (e.g., Laarman and Sedjo, 1992; Sedjo, 1983; Vitug, 2000; Leonen, 2000; Klemperer, 2003) including plantation forestry (Kanowski, 1992; Evans, 1992; Laarman and Sedjo, 1992) but PNG has just recently drafted its reforestation policy. The PNG National Reforestation Policy was first drafted in 2003 and revised in 2005 and was approved by the PNGFA Board. The draft policy was submitted to the National Executive Council for approval but it is yet to be endorsed by the government (Pole-Dembis, Telecon; 10:55 am 12/2/08). The draft policy is awaiting endorsement but the policy appears to favor the socio-economic component and ignores the ecological component which is more fundamental to sustainability.

The slow rate or poor performances of plantation forests development in PNG though plantation began in 1960s were attributed to land issues and finance among others. This can be clearly seen as deforestation and land degradation exceeds forest replanting rate. The National Forest Policy briefly mentioned Reforestation/Plantation Forestry but provide inadequate incentives for promotion of reforestation. Further, PNGFA needs to reconsider its policies especially in the FMA and TRP conditions and amend clauses to allow for follow-up land uses if reforestations by companies are to be promoted. The current FMA concept does not allow follow-up land use so how can the company revisit its reforestation activities once the project (FMA) ceases operation. There is a need to amend clauses in the FMA to allow for the companies to revisit the reforestation projects.

Policies must be compatible with ecology and as can be seen in areas where sound policies are in place, the forest can be managed sustainably and provide adequate products and services, thus aiding sustainable development. For example, New Zealand only has 0.05% of the world’s forest resources but they are placed in the top 20 global forest products suppliers (McLaren, 1996) because of its intensive sustainable management policies and extensive plantation forestry development. Similarly greater expansion of plantation forestry occurs in the southern hemisphere, notably Argentina, Chile, Brazil and Asia where public policies and markets were more conducive to plantation forestry (Kanowski, 1997).

It is imperative that appropriate action must be taken to address the issues regarding plantation forest development and practical action plan must be implemented sooner than later. The action plan should include not just policy measures from the government and supportive roles by line agencies but more importantly how to make forest plantation activities an attractive economic, social and environmental proposition to investors/organization by examining various financing options and provide policy and legal support to ensure the Reforestation Goals are achieved.

10.0 RECRUITMENT: REFORESTATION STAFF

As we move to reforestation, we have demonstrated our continued commitment to sustainable forest management and have began on recruiting three professional staff to drive our reforestation goal. The positions were advertised in the media late last year and a large number of applications were received. The applications will be screened and recruitments will be done shortly to take charge of the reforestation programme. The three positions include a Reforestation Manager to oversee the Reforestation Programme and two officers to be based at the project sites in Kamusie and Asengseng.

11.0 CONCLUSIONS & RECOMMENDATIONS

Reconnaissance was made to existing plantations in Ulabo and SBLC including FRI Trials in Lae as prerequisites to selecting our species for the proposed reforestation project. The findings indicated that site conditions does not differ much accept that slight variations in rainfall and soils were observed. Further, the climate and site conditions observed were typical of lowland Papua New Guinea and can support the growths of Kamarere, Talis, Erima, Taun and a host of other species. The growth of the different species also indicates site specific especially Talis which is well suited to swamp and waterlogged sites while Kamarere thrives well on any soil condition but prefers deep soil with sandy loam to clay loam as in the case of Ulabo and SBLC. Surprisingly, Taun can be among the fast growing species like Kamarere, Talis and Erima. With these findings, the following is recommended for immediate deliberations and actions.

1. Based on the findings, it is strongly recommended that Kamarere, Talis and Taun be introduced to Kamusie and elsewhere with similar site conditions as primary species for reforestation along with Walnut, Teak, *E.pellita* and Erima including others as secondary species for research and further observations;
2. To demonstrate our commitment to reforestation thereby promoting sustainable forest management, it is recommended that the recruitment for the Reforestation Manager and Plantation & Nursery Officers be facilitated promptly;
3. It is recommended that RH management commence dialogue with PNGFA on the possibility of RH purchasing existing state plantations and do reforestation and harvesting concurrently - an excellent start on our reforestation programme;
4. It is recommended that we begin dialogue with PNGFA to source counterpart funding for our reforestation projects through the reforestation levies that we have paid or should we forgo the reforestation levy and do reforestation ourselves; and
5. PNGFA to support in the Reforestation initiative by Corporate Agencies especially in Policy and Legal aspects (e.g., need to amend concepts in FMA to allow reforestation especially in areas identified to be not possible for regeneration naturally).

12.0 REFERENCES

Cannel, M.G.R (1999): Environmental impacts of forest monocultures: water use, acidification, wildlife conservation and carbon storage. In: Boyle, J.R., Winjum, J.K., Kavanagh, K and Jensen, E.C (Eds), "Planted Forests: Contributions to the quest for sustainable societies," Forestry Sciences, Kluwer Academic Publishers, Netherlands. p. 5-9.

Evans, J. 1992: Plantation forestry in the Tropics (2nd Edition). Clarendon Press, Oxford, UK.

Houghton, R.A.; Skole, D.L. (1990): "Carbon." In the earth transformed by human activities, ed. B.L. Turner. New York: Cambridge University Press.

ITS Global 2007: The Economic Contribution of Rimbunan Hijau's Forestry Operations in Papua New Guinea: Report for Rimbunan Hijau (PNG) Group, Melbourne, Australia.

Kanowski, J.P. (1997): Afforestation and plantation forestry for the twenty-first century. X1 World Forestry Congress, Antalya, Turkey. Vol.3: 12. Retrieved on 16th October 2004 from http://www.fao.org/forestry/foda/wforcong/public/v3/t12e/1- 1.HTM.

Kanowski, P.J. and Savill, P.S (1992): Forest plantations: towards sustainable practice. In: Sargent, C and Bass, S (Eds), "Plantation politics in development. Earthscan, London. p.121-151.

Klemperer, W.D. (2003): Forest Resource Economics and Finance. W.David Klemperer, United States of America. p.204-498.

Laarman, J. G.; Sedjo, R.A. (1992): Global Forests: Issues for Six Billion People. McGraw-Hill, Inc. United States of America. p 297

Leonen, M.M.V.F (2000): NGO Influence on Environmental Policy. In: Utting, P (Ed), " Forest Policy and Politics in the Philippines-The Dynamics of Participatory Conservation," Ateneo de Manila University Press, Philippines. p.----/

Mathrani, S. (2003): Evaluation of the World Bank Group's Activities in the Extractive Industries, Background Paper: Papua New Guinea Case Study. Retrieved on October 24 from http://www.siteresources.worldbank.org./intpapuanewguinea/resources/ocd-ccs-papua.pdf.

McLaren, J.P. (1996): Plantation Forestry and the Environment: Environmental Effects of Plantation Forestry in New Zealand. FRI Bulletin No. 198. New Zealand Forest Research Institute. Retrieved on 29 October 2004 from http://www.warrenforestrycom/pdfs/plantation.pdf

Munasinghe, M. (2001): 'The sustainomics trans-disciplinary meta-framework for making development more sustainable: applications to energy issues,' International Journal of Sustainable Development, vol. 5, No.1/2. pp 125- 182 (In YaleRIS-Course Packet Publication FES 842a: Economics of Sustainable Development and Policy Considerations).

PNGFA (2003): Papua New Guinea Forest Authority-National Reforestation Policy Paper (Draft). Ministry of Forests, Papua New Guinea.

Robinson, R.B.; Sallie, B.L.; Soon, W.; Robinson, Z.W. 1988: Environmental Effects of Increased Atmospheric Carbon Dioxide. Green House Network: The FAQS of global warming. Retrieved 29 October 2004 from http://www.greenhousenet.org/resource/faqsglobalwarming.html

Schultz, R.P (1999): Loblolly-the pine for the twenty-first century. In: Boyle, J.R., Winjum, J.K., Kavanagh, K and Jensen, E.C (Eds), "Planted Forests: Contributions to the quest of sustainable society," Forestry Sciences, Kluwer Academic Publishers, Netherlands. p. 71-88.

Sedjo, R.A. (1983): The Comparative Economics of Plantation Forestry: A Global Assessment. Resource for the Future Inc., Washington, D.C. United States of America. p. 1-26.

Sharma, N.P. (1992): Introduction. In: Sharma, N.P (Ed), "Managing the World's Forests: Looking for Balance Between Conservation and Development," Kendal/Hunt Publishing Co. Iowa, United States of America. p.1-26.

Shepherd, K.R. (1986): Plantation Silviculture. Martinus Nijhoff Publishers, Dordrecht, The Netherlands.

Vitug, M.D. (2000): Forest Policy and National Politics. In: Utting, P. (Ed), "Forest Policy and Politics in the Philippines-The Dynamics of Participatory Conservation," Ateneo de Manila University Press, Philippines. p. 11-39.

Woodwell, G.M. (1992): "The role of forests in climate change." In: Managing the world's forests: Looking for balance between conservation and development, ed. N.P.Sharma. Kendall/Hunt Publishing Company, Iowa, United States of America. p. 75.