AN EVALUATION OF FORESTRY METHODS AT CLOUDBRIDGE:

Comparison with commonly used and recommended forestry methods in tropical forests, especially in Costa Rica

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Contents:

1. OBJECTIVES OF THE STUDY

Cloudbridge is a private nature reserve in a cloud forest adjoining the highest mountain in Costa Rica, Mt Chirripo. The reserve has three purposes:

1. To reforest a deforested part of the tropical cloud forest, and protect existing natural forests on the Reserve.
2. To employ local people and get them involved in conservation and reforestation.
3. To create a natural area for research and recreation.

The largest part of the reserve's reforested area in being left in as natural condition as possible after the trees are planted and maintenance of young growing saplings is carried out. In addition, some parts of the reserve have been established to be more like commercial plantations, which generate economic value and cuttings are allowed in the future, when trees grow older and are ready for harvest. The income from this harvesting will be used to support Cloudbridge in the future. Hence the goals for the forestry practices in these stands are to yield profits to cover ongoing costs of the reserve. These areas are:

Area 1. Three rows of trees (*Alnus acuminata* and *Cupressus mexicana*) on each side of the Main Trail (between the Quebrada Lloro and the gate to the River Trail) planted in 2002. Originally approximately 1000 trees were planted in this area.
Area 2. Approximately 600 trees (approximately 5 different native species) planted in the lower section of Gavilan in Aug. 2005.
Area 3. In addition, a section of Gavilan has been allocated to 4 individuals who have worked at Cloudbridge for their own “harvestable” trees (100 each, 400 total).

Areas 1. and 2. have already been planted and some weed control has been carried out. Area 3 will be planted in 2006.

The aim of this study is to present and introduce forestry methods used at Cloudbridge and to compare them to commonly recommended forestry methods in tropical forests. Tropical forestry methods are introduced in several books (e.g. Evans, 1982, Rojas, 2001). These are used as the main references for this study.

This study introduces forestry management alternatives for potential use at Cloudbridge. Some methods, such as the use of fertilizers and nutrients, are excluded because they are inconsistent with the goals of promoting conservation and preserving water quality. Instead the study focuses on management alternatives that could improve the productivity and profitability of the sustainable forestry area. These include choices that could affect the quality and price of the end product, and some recommendations on planting methods such as initial spacing and rotation length. The aim, however, is not to produce a rigorous forestry plan or definite management instructions. This is because of the absence of information relating to the needs of industrial wood users in Costa Rica and the productivity of mixed tropical stands.

2. ESTABLISHING THE PLANTATION

2.1 Tree species recommended

According to Evans (1983) three specific questions must be answered when deciding what species to plant.

- What is the purpose of the intended plantation?
- Which species are potential available?
- What will grow on the sites available?

The primary purpose of the Cloudbridge sustainable forestry areas is economic. Usually highest stumpage prices are paid by the industrial end users. Hence species proper for the industrial uses such as pulpwood, sawtimber, poles and panel boards should be favored. Costa Rica is a net importer of most forest products e.g. sawn wood (FAOSTAT data, 2005). However it has own forest industry enterprises and the is a demand for sawn wood, pulpwood and pillars. The demand and willingness to pay for a certain wood product depends on transportation costs, so end users near San Gerardo de Rivas are perhaps the best potential buyers.

Forestry is an investment, one which should be compared with other investments such as bond and equity funds. To select the most profitable species for planting one must calculate costs and revenues over the rotation time, and discount them to estimate their present values. Timber prices may change, and therefore calculations should be done under different price scenarios. While the best timber prices are paid for high quality timber, but short rotation pulpwood brings income earlier so investment in pulpwood can be more productive.

According to an FAO study (FAOSTAT data, 2005) broadleaved species dominate commercial plantations in Costa Rica. The most common species are is teak (*Tectona grandis*). Laurel and pochote (*Bombacopsis quantum*) are also common plantation species, together accounting for about 15 percent of the plantation area (FAOSTAT data, 2005). These species produce high quality timber. However, they and many other tropical trees grow well only at lower elevations than the Cloudbridge area, which lies at 1500 meters and higher. According to Jimenez et al. (2002) timber species which thrive at higher elevations include *Alnus acuminata*, *Calophyllum brasilience*, *Cedrela tonduzii*, *Quercus copeyensis* and *Quercus costaricensis*.

In the remainder of this study, we focus on timber rather than pulpwood production. The reasons:

- higher stumpage prices for timber logs even in short rotations
- the presence of a sawn wood industry rather than pulp mills near San Gerado de Rivas, and
- the conceivable need for good construction wood also in the reserve area in the future.

Nearly all plantations in the tropics are monocultural, because it makes silviculture simpler (Evans 1983). Sometimes however mixed stands can be a good alternative and even more economically profitable. For example in Finland spruce grows better if mixed with birch. In the tropics mixed stands are sometimes recommended to reduce insect attacts, e.g for Cedro Dulce (Jimenez et al., 2002) and agroforestry methods are recommended for higher timber quality.

2.2 Tree species in Cloudbridge plantations

Cypress (*Cupressus lusitanica*) and alder (*Alnus acuminata*) are the two species planted in three rows adjacent to the Bridge Trail. These species have commercial value, because both species are valuable for construction wood although alder is not very durable. Alder has potential as paper pulp (Jimenez etc., 2002) and cypress is good for pole cosntruction (Rojas, 2001). These species also have been easily available and they are suitable for sites in the Cloudbridge plantation. Both species grow well in high elevations such as at Cloudbridge (Rojas 2001). Accordingly cypress and alder fulfill all the conditions presented in Chapter 2.1.

In the Gavilan area (Area 2), the species planted include: alder, Cedro dulce (*Cedrela tonduzii*), Manzana Rosa and Tirra (*Ulmus mexicana*), and a few experimental mahogany trees (*Swietenia macrophylla*). *Cedrela tonduzii* is well suited to mountain plantations and is native to the Cloudbridge area. Its wood can be remarkably valuable because it can be used in furniture, wooden

ornamentals and for sculpture (Jimenez et al., 2002). According to Jimenez et al. (2002) mahogany grows well only at elevations of 50 – 900 m. Although its timber is one of the most valuable in Central America it cannot be recommended for Gavilan, where the altitude is over 1500 m above sea level. Tirra also has commercial value as it is used for farming tools, floors, railroad ties, wharfs, cupboards, interior decorations and furniture (Moreira and Arnaez xxxx). Mansana Rosa is not a timber tree, but it has fruits and is planted to attract birds and insects.

The 5 species of the Gavilan plantation are interspersed. Mixing with other trees is recommended to Cedro Dulce, because trees will then survive better from the attack of larvae (Hypsipyla grandella), attacks of which could be disastrous in pure stands (Jimenez et al. 2002). The same can be said of mahogany. Alder and cypress will probably grow well also in mixed stands, because they are fast growing species. Although many of the Cloudbridge commercial tree species will presumably succeed in mixed stands, the profitability of mixed plantations compared with pure stands is questionable. Some forestry practices, such as prunings and thinnings, must be done differently than in pure stands, because of the species' different growth rates.

Cedro Maria (*Calophyllum brasilience*) and oaks (like *Quercus copeyensis*) are also timber species suited to high elevations in Costa Rica (Jimenez et al., 2002) and their usage in Gavilan Area 3. should be contemplated.

2.3 Ground preparation

Ground preparation is important to facilitate the saplings' survival and rapid early growth. Ground preparation is undertaken for one or all of the following reasons:

- Controlling the competing vegetation
- removal of physical obstacles to tree growth
- improving soil quality

- modification of natural drainage.

Clearing the vegetation in preparation for planting can be done manually or mechanically. Common methods include burning and the use of chemicals (Evans 1983). Mechanical preparation is usually the most cost effective method. Manual methods, however, are better when the site is difficult for heavy machinery and manual labor is desirable for social reasons (Rojas, 2001). This is the situation in Cloudbridge, because of the steepness of the slopes and the important project goal of employing employ locals. At Cloudbridge, the ground is prepared just before planting by local workers and volunteers with shovels and bush knives. All naturally born pioneer trees are spared.

Small scale burning should be considered as a ground preparation method in Cloudbridge, because it is very effective way of clearing vegetation, reducing the debris on a site. In addition, ash is rich in nutrients and vermin are often killed (Evans 1983). The possibility of the fire getting out of control could be quite easily forestalled in these elevations and small, localized burning would not damage water retention. Burning may even be beneficial for animal and plant species which need burned woody debris and also native pioneer tree species would come and grow quickly in the nutritious soil.

2.4 Planting trees

Tree spacing or planting density is one of the most important silvicultural decisions in plantation establishment. As a rule, very close spacings are extremely expensive and too wide spacing leads to underuse of the site. Accurate growing models of tree species planted in Cloudbridge are not known, when doing this study (this is also because research is probably done only for most common species in pure plantations), so strict instructions are not given. However, according to Evans (1983), an approximate order for spacing, when the aim is to produce logs, is 2.5-4.5 meters between trees. This means ca. 500-

1600 trees per hectare. Table 2 gives more detailed instructions for planting alder and cypress.

According to Rojas (2001) there are four recommended plantation patterns:

- quadrangular, where the distance between trees is the same within and between rows,
- rectangular, where the distance is closer within rows than between rows,
- triangular, where trees grow in triangles, and
- curved array, which helps prevent erosion.

At Cloudbridge, the plantation trees have been planted in rows approximately 2-3 meters apart in rows and columns. The distances in rows and between rows are about same, but the rows also follow the slopes, so the method resembles a curved array. The pits are also always filled with topsoil, which is better than subsoil in erosion prevention. The plantation pattern at Cloudbridge will not significantly hurt the plantation's financial profitability, because cuttings will be done manually and not by machine.

Tree planting in the Cloudbridge plantations is done manually in three stages:
1. marking a line and planting place in the stand,
2. digging the planting pits, and
3. planting saplings.

Trees for each planting pit are selected quite randomly except in plantation area 1, where Alder and Cypress are planted in rows and the upper section near ridge trail where oak species have been selected to mimic the adjacent forests. In addition, fruiting species (manzana rosa, sapote, aguacatillo, ect.) have been planted near and along trails in an effort to attract wildlife.

3. PLANTATION MAINTENANCE

Plantation maintenance in tropical plantations includes several procedures. Some of them are not needed if planting and other plantation establishment stages have been carried out carefully. Replanting is always 3 - 4 times more expensive than normal planting, but is reasonable if saplings mortality is over 20% (Rojas 2001). Singling is method, where young saplings branches are disbudded and best shoot is let grow for better quality (Rojas 2001) and (Evans 1983). Replanting in some Cloudbridge areas has done quite faithfully. This is because tree monitoring is done very carefully and volunteers and workers can easily replant a sapling, if the old one is dead. Singling is not used in Cloudbridge, but it would be good to do this selectively for poor stems while doing weed control in sustainable forestry areas. Partial singling for forked and multiple stems is beneficial for broadleaved trees grown for timber, as at Cloudbridge, even on a large scale it is quite expensive (Evans 1983).

3.1 Weed control

According to Rojas (2001) effective weed control has a great influence on a plantation's economic profitability and it may raise net revenues by as much as 30-50% per hectare. Weeds compete with young trees for light and water, are physical and perhaps toxic obstructions, and have a harmful effect on soil temperature. Weed competition is a serious threat for young trees in the first two years and before the canopy closes and shades out the weeds (Rojas 2001). The need for weed control depends on the tree species, climate and soil quality. However all trees benefit from suppression of competing vegetation (Evans 1983). Weed control can be done manually, mechanically or chemically. In the tropics, the manual method is usually the most efficient.

Weed control is done in the Cloudbridge reforested areas approximately once a month on an as-needed basis, with bush knives. Shade-making shrubs and trees

are pruned at the same time. Once individual trees such as fast growing alders have grown taller and stronger, weed control is no longer needed.

3.2 Low pruning and pruning

Low pruning is the removal of the tree branches to a height of about 2m up the stem at or just after the time of canopy closure (Evans 1983). According to Rojas (2001) low pruning is method done in order to:

- Make timber quality better
- Make the access easier
- Improve tree shape
- Reduce the fire hazards
- Reduce the harvest costs
- Make tree physically better
- Control the tree dimension

Pruning is also recommended for some species to reduce insect attacts (Jimenez et al., 2002). The need for pruning varies among different tree species and some of them are self pruning better than others. Pruning requirements also depend on the planting density, since fewer trees per hectare result in thicker branches. Low pruning can be done for every tree or for 20-50% of trees in a plantation depending on which timber will be used (Evans 1983).

Low pruning can be seen as the first pruning of a series done over several years. According to Evans (1983) there are two main considerations for later pruning, silvicultural and technical. The silvicultural need depends on natural pruning which is further dependent on the tree species and plantation density. The need to prune mainly results from the aim to produce high-grade timber. If the goal is pulpwood or low-grade sawn timber, pruning is not advantageous. According to Rojas (2001), the time for high pruning is when the stems reach 3-10 meters, when the trees are taller and not every tree should be pruned.

Pruning is not always recommended. According to Rojas (2001), trees with bad shape, sick trees and small and weak trees should never be pruned. In these cases pruning is a waste of time and money, and may even cause diseases for the trees pruned. Trees suitable for pruning should be pruned in an accurate and careful manner. For comparison, pruning recommendations for boreal forest zone trees in Finland are very strict: the pruning of pine trees, for example, is allowed only if the tree's breast height diameter is 7-13 cm, branches are thinner than 2.5 cm and the living canopy will be at least 40% of the tree's height after pruning. Although trees are totally different and grow faster in the tropics, pruning should be done cautiously because of the risk of disease and rotting. Trees should never be over pruned. According to Rojas (2001), the best time for pruning is the end of the dry season, because then the risk of disease is least, many trees are without their leaves and healing is easily achieved. Pruning does not always achieve its aim (Evans 1983): adventitious branches may be easily formed and developed next to the pruning scar for some species, such as teak.

Giving recommendations for pruning at Cloudbridge is quite difficult for at least two reasons:

1. Pruning recommendations and studies made of pruning profitability are usually made for pure monocultural stands, so the same instructions cannot be directly applied to mixed stands, where trees will probably not grow at the same pace and the canopy does not close evenly.
2. No clear instructions for pruning methods of the Cloudbridge tree species were available at the time of this study. Available recommendations are vague. This is also because of a lack of research on some species.

However Table 1 gives some general guidelines for pruning of species planted or potential species in Cloudbridge, introduced in chapter 2.2. They are mainly based on the book by Jimenez et al. (2002).

Table 1. Pruning recommendations for Cloudbridge trees. Scale: xxx=much recommended, x=little recommended and - = never recommended

Tree specie	Low pruning	Pruning	Comments
Alder	x		Fast growing, needs timely pruning, but need depends on use.
Cypress	x	xx	Pruning is recommended escpecially if soil is very fertile. Persistent branches
Cedro Dulce	xx	x	Recommended because of larvae attack and wood quality.
Mahogany	xx	x	Recommended after shoot-borer attacks and wood quality.
Monsana Rosa	-	-	No commercial value, no need for pruning
Tirra	x	x	Valuable timber, so pruning lightly recommended (no information).
Cedro Maria	x	x	Valuable timber, so pruning lightly recommended (no information).
Roble blanco	x	x	Lightly recommended because of better quality.

4. THINNINGS AND ROTATIONS

4.1 Stand development and thinning decisions

When trees in a plantation or in the forest grow older, competition between individual trees begins in ways such as root and crown competition (Evans 1983) and (Rojas 2001). Some of the trees can obtain a dominant canopy position, but the result of this competition is slower overall growth, higher mortality and weaker individual trees in the plantation. Intermediate cuttings or thinnings should be done to harvest otherwise naturally dying or weak trees, and to create better growing possibilities for the remaining trees. The aim is to direct the site's resources toward the most valuable trees and thus produce more valuable logs for subsequent cuttings and finally for the regeneration cutting. According to Rojas (2001) intermediate cuttings are neglected too often in Costa Rica. This reduces forest owners' revenues during the rotation. However, sometimes thinning may be impractical; in such cases the most profitable course is to allow the trees to reach the desired size and then clearcut them.

In tropical plantations, thinnings are normally carried out several times. The first is done a few years after canopy closure (Evans 1983). The number of thinnings depends on the species of tree plantation and its rotation time. According to Evans (1983), the timing of thinning is usually based on stand height, living crown ratio, or when the current annual increment falls below the mean annual increment. For example *Pinus patula* in Kenya is thinned three times in a 30-year

rotation while teak plantations in India are thinned six times during a 70-year rotation (Evans 1983). These recommendations are for monocultural stands. The first thinning is the most important thinning, because it affects all the subsequent operations and log size assortments to be produced. The chief thinning methods are systematic and selective thinning (Evans 1983). Systematic thinning is a simple method for a single-species stand. Selective thinning can be low thinning or crown thinning. Low thinning removes only lower canopy trees, but in crown method dominant canopy trees can also be removed to favor the most valuable tree individuals (Evans 1983). Thinning practice often lies somewhere between these categories.

Giving recommendations for suitable thinning methods for the three Cloudbridge plantation areas is difficult for the reasons mentioned in chapter 3.2. However, following Rojas (2001), thinning and rotation recommendations for pure stands growing alder and cypress are presented in Table 2; they should be adopted for Cloudbridge Areas 1 and 2. Otherwise thinnings should be done to favor higher quality log trees like *Cedrela tonduzii* and oaks. Selective thinning the by low- or crown method is the right approach for Cloudbridge, but the alder and cypress trees should be removed first.

4.2 Rotations and regenerations

Rotation length is the planned number of years between planting and clearfelling and replanting or natural regeneration. The plantation manager chooses the rotation based on his goals, such as the desired log size, volume yield or profitability and regeneration method wanted. There are physical, silvicultural, technical, financial and maximum volume production rotations (Evans 1983). A “financial rotation” length can be defined in several ways, such as those described by Pukkala (2005):

Terminology: u = rotation length, N_t = Net revenues in year t, i = interest rate (e.g. 0.03) and t = year of thinning or other action

1. Highest forest rent rotation. Aim is to maximize annual net revenues during the rotation (cut when value growth equals average net revenue). Criterion requires that there are no liabilities (debt) nor any opportunity cost for equity. Same as (2.) with interest rate 0.

$$\text{Max} = \frac{\sum_{t=1}^{u} N_t}{u}$$

2. Highest lant (soil) rent rotation. Maximizes forest profits with certain discount rate. Is comparable with bank savings at the same rate. Lant rent: cut when relative value growth (%) equals discount rate (opportunity cost of capital) adjusted by soil rent component (in Finland this adjustment can be approximated by increasing the discount rate by 25%, for example from 4% to 5%).

$$\text{Max} = \frac{\sum_{t=1}^{u} N_t(1+i)^{u-t}}{(1+i)^u - 1}$$

The use of these calculations requires information on tree value growths, prices and costs, and should be done under different scenarios. This method is the basis for forest planning computer programs that produce plans based on, for example, a forest owner's goals for profitability as well as recreational value.

The various tree species in the Cloudbridge plantations grow very differently. Alder and cypress are fast growing trees, and a reasonable rotation is 15-20 years (Table 2). Rotation lengths for other Cloudbridge species, like oaks, producing high quality timber should be longer. But this also depends on whether there is demand for small logs, and needs detailed calculations using timber

prices and management costs. For comparison, teak plantations in Thailand were most profitable with 25-year rotations (Niskanen and Saastamoinen 1996).

Table 2. Planting, thinning and rotation length recommendations for alder and cypress

	Thinning year and growing stock after action:						
Tree species	**Plantation spacing (density)**	**1. thinning**	**2. thinning**	**3. thinning**	**Number of thinnings**	**Rotation age**	**References**
Alder	3*3	4/	8/	15/250 to 350/ha	at least 2	20	Rojas 2001, Russo 1994
Cypress	3*3	4/	8/	12/	3	15-20	Rojas 2001

5. SUMMARY

This study describes the theoretical basis of some important forestry methods and offers recommendations for sustainable forestry at Cloudbridge. Adequate resources for developing the theoretical basis were available when doing this study in October 2005 in San Gerardo de Rivas. However the broad scope of the subject, the lack of detailed information on the productivity of mixed tropical stands, and of the tree species used in the Cloudbridge plantations, forced the author to give only broad recommendations. However there is no better practice than good theory.

This study focuses on the three areas and six tree species mentioned earlier. When selecting trees in for Gavilan area 3, planting Cedro Maria (*Calophyllum brasilience*) and oaks should be contemplated. Silviculture would be easier if fewer species are planted in each area. Maybe a mixture of two high quality species would be better. Pure single-species stands are not recommended for Cloudbridge because they provide inferior conservation and recreational value. In addition, even if there are no planted oaks in the areas discussed in this study, there are in other areas of Cloudbridge. If cutting these single trees later is considered, such cutting should be done very carefully. Selective cuttings may

have disadvantages such as weaker regeneration or the growth of light-demanding species.

A further note on profitability. Forestry work with machinery is more efficient than manual work in most aspects of silvicuture, especially in large plantations. However it is cheaper only if labor costs are high, machinery is reliable, infrastructure like roads and service facilities exist, and workers well educated (Nummelin 1988). Thus manual work in all of Cloudbridge forestry stages is economically as well as socially justifiable. However, some mechanical help, like use of ATVs, should be considered in some stages.

The financial value of forests relates mainly to wood production, which is the principal goal of these Cloudbridge plantation areas. In many countries governments pay subsidies to private forest owners for sustainable forest management, in order to boost their forestry sector and possibly the national economy. These grants motivate private forest owners to take actions which otherwise would be unprofitable. At least one kind of government allowance is available in Costa Rica. The Fondo Nacional de Financiamento Forestal in Costa Rica grants allowances for forest owners if they reforest, preserve or use their forests a sustainable way. These funds are paid for forests environmental services such as sequestering carbon dioxide and are quite unique in the world (Hirvonen and Kanninen 2003). If such grants are available to foreign land owners, Cloudbridge should apply for these grants.

There is also some value in the fruit trees such as Mansana Rosa. Though they may be difficult to value in financial terms, they are important for conservation and recreational value. More generally, it should be recognized that planting trees at Cloudbridge creates economic value for the surrounding communities. The higher is the financial profitability of a forestry enterprise, the greater is the overall positive economic impact (Niskanen and Saastamoinen 1996).

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