Celsius Degree / Grau Celsius

The magic *Eucalyptus* plantation forests

Celso Foelkel

The genus *Eucalyptus* is originated mainly from Australia, where hundreds of species grow naturally, from shrubs to majestic trees. Due to the excellent adaptation in other environments, the rapid growth and the wood quality, these trees have been quickly disseminated over the world, to many different countries. Today, you may find eucalyptus trees in a large variety of environments, specially in tropical and semi-tropical regions of the planet. *Eucalyptus* may be found in all Latin American countries, in Africa, Asia, Australasia, middle East, Mediterranean European countries, etc. In United States of America, they grow well in Florida and California. However, not all environments are good to these trees. They are very sensitive to frosts, droughts and snow fall. For these reasons, the eucalyptus trees are unable to grow and to provide wood in dry weather regions, because the hydric deficit in the soil; or in areas submitted to very severe cold weather. Most of eucalyptus have low resistance to temperatures close to the freezing point of the water.

In the early days, eucalyptus were planted aiming firewood, or as a source of wood to farmers and railways. Along those old days, the main objectives of the wood planters were volume and suitability to the end-use. Pretty close as they are today. The rule was to plant the right species to the specific utilization or end-use. High density wood species were planted to generate dense biomass for firing in the boilers of the train locomotives. This dense wood is also suitable to other uses: poles, fences, railway sleepers, etc. At that time, there was a perfect marriage between the eucalyptus and the railroads.

The use of *Eucalyptus* species as pulpwood is relatively recent. Shyly, they were introduced to the pulp manufacture between 1930-1950, mainly as a secondary source of fibers in wood blends. The first successful industrial operation based on 100% eucalyptus fibers for fine white paper manufacturing resulted in an interesting dispute between Spain and Brazil. Both claim to have the privilege of doing this first. No matter who had the honor to be the first, the important is that this creative operation allowed countries such as Brazil, Chile, Morocco, Spain, Portugal, South Africa, and surprisely Norway, to become important market pulp producers based on these magic fibers.

Since eucalyptus trees have difficulties to regenerate naturally in regions outside their homelands, farmers and foresters were obliged to develop techniques to establish plantations, based on seedlings produced in specially designed nurseries. The success of all plantations till now are very much dependent on the quality of the seedlings, no matter they come from seeds or cuttings in clonal propagation. These young baby-trees are transferred to the ground in an orchestrated highly technological process. In doing the right moves and making the right decisions and choices, the trees are able to grow in amazing rates. It's important to emphasize that there are key technological points involved in developing highly productive eucalyptus plantations. It's not a matter of lucky or a simple procedure to be taken for anyone. Even breeding the genetic material and providing superior cloned seedlings to the foresters, if the silvicultural and forest management techniques are poor, the forest yields are also to be poor. Why? Because all living organism depends on two main attributes to grow, to develop and to externalize all potential they have in their genomes: the genetic heritage and the environment they live. By developing technologies to combine both, a winning forest industry has been created in recent years. For these reasons, eucalyptus planted forests are very productive in some blessed areas of this planet. But this is not a gift received from God or from Nature. Photosynthesis is a privilege to many, but only few were able to utilize it to grow superior trees. There is a lot of efforts and science involved. Several countries are taking these chances. In addition to the former list of the market pulp producing countries, there are other countries in the world growing eucalyptus trees, and with high potential to become important pulp and paper manufacturers: Uruguay, India, Argentina, Congo, Australia, New Zealand, Colombia, Peru, Venezuela, Vietnam, China, Mexico, Indonesia, Malaysia, France, Italy, and many others. They have to find the right environment and to select the most convenient genetic materials to be planted. Some eucalyptus clones growing in fantastic rates in Chile, for example, may not be suitable to be planted in Malaysia, and vice versa. The idea of robbing genetic materials from one place to be used in another is just a fiction movie. Surely, it may become a disastrous plantation in many cases, victim of pests or diseases, or showing a poor performance in the ground. For these reasons it is important to locally value the bank of genetic materials, based on different species, provenances and ecotypes.

Scientific and technological procedures were developed to allow wood and fibers to be more oriented to the pulping and papermaking processes. At the same time the wood is being specialized and engineered, the forest operations have to be safe to the environment, avoiding negative and harmful impacts to Nature. This has to be taken into consideration to prevent the impact to the environment of the low genetic diversity cultures.

The dominant species of *Eucalyptus* planted for papermaking fibers are: *Eucalyptus grandis*, *E. saligna*, *E. globulus*, *E. urophylla*, *E. camaldulensis (* known also as *E. rostrata)*, *E. globulus maidenii*, *E. viminalis, E. dunnii, E. regnans*, *E. nitens, E. urograndis* (a hybrid between *E. urophylla and E. grandis*) . These marvelous species deserve our recognition not only because the products and productivity they offer. They provide their bodies and their cells to the manufacture of daily products to Mankind. But this is not the whole story: after harvesting the forests, the eucalyptus stumps sprout and regenerate another forest, that can be managed for high productivity again. Science and technology helped the process to become productive and environmentally friendly.

The science has also helped to engineer the most convenient wood quality according to the final end-use. The short eucalyptus fibers may be converted into a large variety of products, either alone (100% eucalyptus fibers) or blended with other fibers (for example, blends with softwood fibers as the European are used to do very well). There are two important end-uses for the eucalyptus fibers: tissue and P&W papers. However, there are hundreds of other possibilities, running from dissolving grade pulps to insulating papers. Wood fibers harvested from well-managed plantation forests provide the specifications the market require: cost, homogeneity, quality, and productivity.

The quality of pulps and papers is very much dependent on the physical and chemical features of the fibers and other wood anatomical components. Many of these tree characteristics have strong heritability and they may be transferred from parent trees to the next generation of trees. A combination of traditional tree breeding and hybridization/cloning allows the forester to control these properties and to engineer trees with woods and fibers which provide superior pulps to specific end-uses. However, not only the genes are responsible to design the wood and fiber properties. Several parameters have also to be controlled, such as: the selection of the soil; the type and amount of fertilizers; the rotation age of the forest; the species being planted; the two or three species combined in the genome of the trees being cloned; etc. Furthermore, paper is not made at the forest. Only pulpwood, the raw material, is. It is important to understand the innermost relationships among the wood quality parameters and the pulping and papermaking processes.

Plantation forests for commercial and industrial purposes are recent in our history. They became necessary when the inventory of natural forests decreased, and when more quality and homogenous fibers or wood were made required. The technological achievements in less than one century may be ranked as outstanding. There are not substantial areas with plantation forests in the world, but the trend is for growth in the coming years. According to the FAO Global Forest Resources Assessment in the year 2000 (Food and Agricultural Organization of the United Nations system), there are about 187 million hectares of planted forests, being about 48% for industrial purposes. From this total area, 25% are small forests planted by rural farmers for their local needs, for small business among farmers, or planted with environmental conservation purposes. The eucalyptus planted forests occupy a global area of 18 million hectares. India and Brazil are the leaders in planted area, and Brazil ranks first in forest productivity. India has about 4 million hectares of eucalyptus plantation forests and Brazil roughly 3 millions. This is only a small fraction of the total territorial area of these two countries have. Nevertheless, there are opponents to the plantations: they imagine a critical future with the world covered by mono-cultures, with a tremendous lack on biodiversity. Many of the opponents are far from understanding the real benefits accruing from these fast growing forests. Because these forests are able to produce a lot more wood per unit of area, the first main benefit is the possibility to supply with wood the world population requirements without damaging the native forests and using much less land. The wood from plantations allows reducing the pressure over endangered woody species, avoiding indiscriminate harvesting of these species for wood utilization by humans.

In Brazil, eucalyptus plantations grow at an average rate of 35 to 45 solid wood cubic meters/hectare per year (equivalent to 50 to 70 stere/hectare per year or 5.5 to 8 cords/acre per year). This corresponds to 10 to 12 admt of bleached pulp/hectare per year. Considering a 6 or 7 year cycle, an average forest stand produces 250 to 320 m³ per hectare at harvesting. If someone recognizes that today's annual world pulp demand is about 180 million admt, an area of 18 million hectares of eucalyptus plantations would be able to supply all world pulp demand. We are talking about 2.1% of total Brazil territorial area. This is far from the 4.9 million hectares of total planted forests in the country, including eucalyptus, pines and acacia.

As far as Brazil is a reference in terms of silviculture and genetics for eucalyptus, it is important to tell a short story about these technological achievements. Fortunately, the key points were successfully found and actions were taken at the right time to magnify the opportunities.

Eucalyptus were first introduced in Brazil late in the 19th century, as an ornamental tree or for utilization by farmers as an inexpensive source of wood. For industrial applications, it is reported a huge introduction of several species in the year 1904, or a century ago. This introduction was made possible due to the wishes and efforts of a Sao Paulo Railway company, aiming to obtain wood to run its business activities (firewood, poles, sleepers, etc). Some species proved to grow well and to match with the demanded requirements in quality. They were: *E. paniculata*, *E. tereticornis*, *E. urophylla*, *E.citriodora*, *E. grandis*, *E. saligna* . As a consequence of this massive introduction, this Sao Paulo Railways was able to plant the forests to supply their needs and also started to trade wood, seeds, and other by-products from this business. A huge technical development came together and forests yields easily reached 15 m³/hectare per year in early 1950s. However, this level of productivity became difficult to be surpassed, and stopped to grow. The reason was soon identified: the domestic seed supply, coming almost entirely from the Sao Paulo Railways plantations, was contaminated by hybrid seeds. *Eucalyptus* species are not restrictive to sex among different species. This is in opposition of most living organisms, that do not cross to other species. Also, another feature of this sexual contamination: the hybrid seeds are fertile and viable. These types of crossing are common in eucalyptus, and the result was an enormous variation in the forest stands and wood quality. For these reasons, the Brazilians went back to Australia and to Indonesia (*E. urophylla* homeland) to selected species , provenances and superior trees again. The game started in the second half, but with a lot of experience acquired in the previous half century. The reintroduction of new genetic material had a boom during the 1970's. Special care was taken from that time onwards to avoid hybridization in seed production and highly sophisticated seed orchards were established. Along these years, the vegetative propagation of eucalyptus was also developed in two fronts: cutting/cloning and tissue culture. Although very optimistic in the beginning, tissue culture proved not to be feasible for commercial seedling production, but it is being very helpful to speed up the forest breeding programs, shortening many breeding cycles. Along the 1970s and 1980s, the forest stands based on improved seeds were able to enchant foresters with growth yields of about 30 m^3/hectare per hear. Till the 1980's the hybrids were scarce in the commercial plantations, with the exception of Aracruz Celulose company, in the state of Espirito Santo. Early 1970s, Aracruz was born with the aim to build an enormous market pulp mill in a semi-tropical area, in the shores of Atlantic ocean. Massive plantations of *E. grandis* and *E. saligna* were established to provide the mill wood supply. Because the warm and humid weather, the forests started growing in very attractive rates. The excitement did not last for too long. Both species showed to be sensitive to a fungus (*Cryphonectria cubensis*) disease, known as canker of the eucalyptus. The threat was frightening, because the disease started to send roots to Sao Paulo, Minas Gerais and Bahia, other important areas with eucalyptus forests. Initially, the problem was considered to be easily solved by changing the species to others more resistant to the disease. However, tropical eucalyptus did not perform as well as *E. grandis* and *E. saligna* in pulping and papermaking. Also, the forest yields were far from the targets. Late 1970's and early 1980's the problem was solved by a combination of the genomes of two species (*E. urophylla* and *E. grandis*), originating a hybrid baptized as *E. urograndis* . *Eucalyptus grandis* brought fast growing and E. urophylla the resistance to the disease. The combination was perfect. The unexpected advantage was the gain in volume: the hybrid was more productive than the parent species, because a biological feature known as heterosis or hybrid vigor. The hybridization was a success and Aracruz decided to commercially implement the cloned forestry. It is important to mention again that seeds from the *E. urograndis* hybrid are fertile and viable. However, the F1 generation, as it is known the progeny in biological terms, is very variable. The daughter trees may vary in characteristics from one parent species to another. The result is a lack of homogeneity in the forest and in the wood quality. However, these hybrid forests are amazing providers of superior trees, with outstanding characteristics to be propagated in a vegetative procedure. It's only a matter of finding the superior trees and select them for cloning. Commercial cloning of eucalyptus forests started initially with Aracruz, but in the 1990s, most of the forest-based companies in Brazil were implementing this technique. Crossings are possible to be controlled, most of the eucalyptus are able to be crossed, it is a kind of endless game. New species gained importance for crossings: *E. globulus, E. dunnii, E. deanei, E. viminalis, E. camaldulensis, E. maculata,* etc. The Brazilian foresters had a hard work to identify the trees with the strict specifications they had chosen, but the results were rewarding. Today, cloned eucalyptus forests are dominant in Brazil, but they are not exclusive. A certain percentage of forests are still being planted with seeds, obtained from these different "laboratory" crossings, or by introduction of new genetic material coming from different areas or suppliers. The reason of doing this is to allow the possibility of new developments and to keep the chance of finding new superior individuals to be multiplied by cloning. It's a natural way of doing forestry, very common in agricultural crops. Forest research only speed up the process that Nature could take centuries to do, or never do, although naturally possible. It is the case of two species being crossed in the nursery, but one coming from Indonesia, and another from Tasmania. (*E. urophylla* and *E. globulus*).

The Brazilian eucalyptus forest based industry found a room for continuous growth, overcoming threats and fears. The reward is the accumulated knowledge and the positive manner to face the future, with optimism and confidence. Fortunately, in Brazil, several universities and R&D centers have also grown together to the development of the forests and the industry. They have strong roots to keep going, mainly because the close linkage to the industry.

Back to the world scene, it is also clear to everybody that plantations are important to the economy and to the environment. NGOs have also changed attitude when opposing plantation forests. Excellent tools were developed to prove the sustainable forest management. Since mid 1990s, forest certification has deserved a growing acceptance as a procedure to guarantee sustainability in the forest operations, from seedling to harvesting. Another positive factor that is driving improvements in the environment is the motivation of workers. Plantation forests play an important social role. Thousands of rural jobs are generated, and people working to forest companies are trained, educated, and in general motivated with the implementation of the IS0 14000 or FSC certification schemes. Sustainable development includes human beings, environment, economical return to investors and technology. The word technology was included in my definition of sustainability because its importance in providing the ways to minimize the impacts of the operations.

Let's have a short look to the technologies are being used to obtain highly productive eucalyptus forests. They all have a touch of sustainability:

1. Complete fulfillment of the applicable forestry, social and industrial legislation;
2. Forest certification via IS0 14000, FSC or other forest certification schemes;
3. Utilization of "clean areas", usually degraded pastures or exhausted areas from former intensive agricultural utilization;
4. Eco-efficient planning of the areas, since the area is to be acquired for plantation;
5. Utilization of only the areas suitable for plantation, preserving natural ecosystems for biodiversity enrichment;
6. Selection of adequate genomes or species, according to the previous site evaluation. This allows better use of the site, and prevent wastes or reworks. This means eco-efficiency again.
7. Plantation and harvesting done in mosaics, providing a more complex ecosystem and a more relaxing landscape;
8. Genetic development of effective trees to use less nutrients and less water per produced unit of wood volume or wood weight;
9. Water and evapotranspiration balances;
10. Planning the road structure and the soil preparation to keep rain water restricted in the area and preventing run off and soil erosion;
11. Soil conservation and combat to erosion from the beginning;
12. Soil nutrient balances orientating the fertilizing program along the forest cycle;
13. Biological control of pests and diseases;
14. Complete banning of fire in all forestry operations;
15. Highly efficient systems to combat forest fires, important economic problems and a great harm to Nature;

16. Maximum removal of the wood from the forest land at harvesting, but keeping forest residues untouched at the ground, such as bark, leaves, branches, roots, etc;
17. Combination of forestry to other agricultural activity, in a technique known as agroforestry;
18. Multiple use forestry, meaning that other products may be extracted from the forests other than pulpwood. Eucalyptus forests are source of honey, essential oils, wood for furniture, construction of buildings, wood panels, firewood, charcoal, etc.
19. Intensive utilization of quality control in the forest operations aiming to fulfill the saying "do it right at the first time";
20. Adoption of cleaner production in forestry, meaning to reduce the generation of wastes at the source, minimum use of energy, raw materials, chemicals, etc;
21. Close association with the pulp and paper mills by receiving in the soil valuable industrial residues: ashes from biomass boilers; lime mud, dregs and grits from causticising; composted sludge from wastewater treatment plants; residual water for irrigation; etc;
22. Evaluation of the impact of mechanization in the soil compaction, secondary vegetation, etc;
23. Continuous programs of cooperative R&D;
24. Social inclusion of rural workers in a more developed and educated society.

Do you believe we are placing high wood production into a second level in a model like this? Certainly we are not! We have room to create more productive forests working based on sustainable forest management. The excessive focus on the genome is good, but not completely required. As mentioned before, the genome is only a piece in this puzzle. Based on genetics, it is possible to speed up the process of trees and wood selection for special purposes, such as resistance to pests and diseases, efficient utilization of nutrients, fiber quality to specific end-uses, etc. The acceleration in tree breeding is considered a competitive advantage. This is a great advantage when you talk about forests growing in less than ten years to become ready for using. This advantage has to be kept and improved. This is the feeling in the segment. For this reason, there are huge efforts being placed in identifying the complete sequence of genes in the *Eucalyptus* genome, and to relate the effect of each gene in the tree and wood features. The forester is aware that genetics is important to help providing the right forest to the right site. For site, we do not mean only geography or weather, but anything from the environment that may impact growth: soil type, sunshine, pests and diseases, ants and termites, soil humidity, soil coverage, etc. Even a reckless worker, when walking in a just planted forest, is considered to be an environmental effect of the site, because he may step in several of the young seedlings. Site and genetics is a marriage to be monitored, controlled and improved. The interactions between them is also important in the orientation for the plantations.

Based on today's level of knowledge, it is possible to predict future eucalyptus forest yields of 80 m³/hectare per year in Brazil, as a result of better genetic material and more efficient control of the site, via fertilization, irrigation, weeds and insects control, etc. Today's average in good stands varies from 35 – 45. There are situations where 60 - 70 have been reached, but not in sustained commercial operation. This potential growth does not depend on a great deal of investigations, but a huge effort to be more efficient in the silvicultural operations practices. Having good and adapted genomes, if forester is able to produce good quality seedlings and to provide food and water to them, and to control limiting factors, a great part of the puzzle will be completed. Weeds, fires, ants, termites, fungi, droughts, frosts are the "bad guys" in the game.

Today's technology allows very good seedlings, good tree survival after planting (over 97% in most cases), efficient nutrient utilization provided by fractionating fertilization, good but not outstanding homogeneity (with enormous potential for improvements), and minimum damage to the environment in the forest operation. Efficient planning is fundamental to prevent overlapping of activities and consequent damages to the soil, to the stumps, etc.

Finally, what about genetic engineering? Is it also helpful? Surely yes! As a supporting tool to map genomes even in the embryo phase, to allow early selection of superior trees, to assist hybridization and controlled crossings, to understand genome architecture, etc. In the long term, even the genetic manipulation of the genome may become a common practice, through the insertion or replacement of genes, or gene rehabilitation, for example. *Eucalyptus* GMOs are not being demanded now-a-days. There are many opportunities using hybridization for combining desirable genes freely available in Nature. However, GMOs are part of a road that science is willing to transit. Because of the long life cycle of a forest, the advantages of GMOs are more limited than in short cycle plants as soy bean, corn, lettuce, carrots, etc.

Summarizing: eucalyptus forest plantations are to become more and more frequent in order to supply wood for industrial purposes. They will continue to play an important role in developing welfare to the communities and possibilities for further scientific and technological developments in search of more sustainable models to the future. We must plant forests. It's a very natural choice. But we need responsible behavior. No doubts about.


Nursery


Young seedlings


Just planted seedling

10 month-old plantation

6 year-old plantation forest

Industrial pulpwood (7 year-old forest)

Harvesting the forest

Environmental equilibrium