EUCALYPTUS CLONES IN THE FORESTRY OF UGANDA

CHAPTER ONE: Status of Forestry in Uganda

1.1 History

In this technical note the word ***forest*** means all types of tree-covered land including; high and medium altitude forests, savannah woodlands, wetland and riparian forests. It is however, very important to note from the outset that the definition of a forest suggested by United Nations Framework Convention for Climate Change (UNFCCC) is erroneous because if used, the entire Uganda may be considered as forested. And yet as of now, out of the 1890 baseline estimate (Table 1), remnants of tropical high (rain) forest are only found in four places (Karani 1993): the majority occurs on the highlands and mountains marking the eastern rim of the western rift valley. Second group of forests is found near Lake Victoria and its islands. Third and fourth groups are found on Mount Elgon of the eastern region and the mountains of the north-east of Uganda respectively. Many people together with key stakeholders like NFA and National Environment Management Authority (NEMA) believe that there are 4.9 million hectares of natural forests and woodlands in Uganda, which cover 24% of the land area. They contend that eighty-one per cent (3,974,000 ha) of this is woodland, 19% (924,000) is tropical high forest and <1% (35,000 ha) is forest plantations. Of course the bulk of the forests belong to private ownership as mentioned below.

Nevertheless, scrutiny of all the past estimates of Uganda's forest cover portrays a high degree of contradictions and, perhaps some form of misconception among the authors as statistics in Table 1 show. In Uganda forests are located either on government, leasehold or customary lands. Of the total forest area, 70% is on private land, while 30% is in the permanent forest estate (PFE). Only about 38% of private forests are tropical rainforests and the rest is forest woodland. Management of the PFE which is estimated to be about 1,881,000 ha is as follows: 60.9% is managed by the National Forest Authority (NFA), 38.8% is controlled by the Uganda Wildlife Authority (UWA) while an insignificant 0.3% is owned and managed by the local governments. Within the PFE 78% is under forests and woodland and the rest is mainly grassland. Undoubtedly, two clear lessons can be learned from these statistics: namely, that the private sector plays a critical role in Uganda forestry and the second lesson is that not all the gazetted forest reserves contain trees – a factor which has often led to conflict in land use in Uganda; in the sense that treeless portions of the reserves are always deemed to be better used for other economic activities.

Table 1. Subsequent estimates of the natural forests of Uganda [THF = Tropical High Forest, LA= Land area and TLA= Total land area]

Date	Forest type	Size (ha in 1^{-6})	%	Area	Authors
1890	THF and woodland	10.8	53.0	LA	FAO 1997, 2001
1890	THF	2.6	12.5	TLA	NEMA 2004/2005
1987	THF	0.08	3	TLA	NEMA 2004/2005
1989-95	THF	<5	24	LA	MWE 2001

Uganda, over 88% occurred in private forests. Indeed encroachment, the practice which is always driven by the ecological refugee (Gadgil 1995) or 'shifted' cultivators (Myers 1995) is especially vicious because encroachers do not belong to the forests and thus have no attachments, knowledge nor motivation to use the resources of the forests in a prudent manner. In the government forest reserves which cover approximately 1.1 million hactares, less than 740,000ha of forest cover: a loss of 34%.

Even the quality of THF in terms of number of species and trees has also declined over time with well over 30% being classified as degraded. Although there is no clear definition or measurement of this degradation, oral accounts from experienced foresters indicate that 75% of Uganda's principal forest reserves have been degraded by heavy mechanical and uncontrolled pit-sawing. Over all estimates put the rate of deforestation at 1.1–3.2% per annum. Estimates by the Forest Department (FD) showed that by 2002, Uganda was losing about 200,000 hectares of forest annually. Of a total of 1.17 million hectares of central forest reserves (CFRs), 58,000 hectares (5%) had been degraded or depleted. Overall, 14 of 500 forest reserves had been degraded. Several causes of forest degradation and deforestation in Uganda have been documented; key among which are:

- breakdown in law and order between 1970 and 1986
- conversion to agricultural land and other land uses
- increase in demand for forest products for domestic and commercial purposes
- higher demand for construction and furniture timber
- weak law enforcement and policy implementation
- urbanization and industrial growth

Conservative estimates suggest that Uganda clears some 80, 000 - 100,000 ha for agriculture every year. Recent data collected by NFA showed that of the 80,000 ha annual deforestation in Uganda, over 88% occurred in private forests. Foresters of Uganda now estimate that about 3,436,000 ha of forests found on private land have been degraded because the land owners regard the forest as a major source of income, and potential agricultural and grazing land. High population growth rate of 3.4% per annum, and expanding human settlement (urban and rural) have also been responsible for the high rate of deforestation in Uganda as forests are cleared to give way to spatial agricultural expansion and settlement. In general, annual rate of deforestation is highest in the woodlands (2.1%) and lowest in the relatively well-stocked tropical moist forests (0.3%). Indeed encroaching on the forests, the practice which is always driven by the ecological refugee (Gadgil 1995) or 'shifted' cultivators (Myers 1995) is especially vicious because encroachers or shifting cultivators do not belong to the forests and thus have no attachments, knowledge nor motivation to use the resources of the forests in a prudent manner.

NEMA has documented a number of underlying factors that have contributed to the decline in the quality and extent of Uganda's forest resources.

Data on forest loss sketched above, without any doubt, tell us that in Uganda wood is one of the most critical resources that is exploited by the majority of the rural poor and wealthy urban people. Poor people exploit wood for energy, construction and furniture making and other manufacturing processes. Charcoal, fuel wood, poles and timber are uncontrollably extracted from these forests.

Forestry therefore makes a substantial contribution to the nation's economic development and well being, although the extent is not fully recognized. In 1999, it was estimated that forestry contributes 6% of national GDP while currently the annual turnover of business in forestry is $ 200m and additional $ 62m from payment for environmental services. Even though the importance of petroleum and hydro-electric power is growing, wood is by far the most important source of energy. In addition to domestic use, wood is widely used in many industrial processes: brick and tile making, tea and tobacco curing, and the baking and food processing industries. Collectively, this level of energy consumption is about 30 times the combined energy from electricity and petroleum. Indeed, some 96% of the national energy is met from woody biomass. That is about 17-20 million tons of air-dried firewood are consumed annually; of which charcoal now estimated at 500,000 tonnes, takes a significant quantity. Roundwood used in rural housing and fencing is estimated at over 875,000m^3 while demand for sawn timber currently estimated at 800,000m^3 is now rising phenomenally given the building boom in every part of Uganda. Incidentally, the rise in the demand for sawn timber is accompanied by the rise in the wasteful production system called pitsawing. The bulk of pitsawing is coming from both public and private owned forests.

The other priceless, so-called common goods (non-wood forest products e.g. medicine) and services of forest ecosystems are exploited as a matter of birth right. Indeed, forest ecosystems provide multiple services, most of which are non-solicited and accessed openly by anyone at any time. That is why they are sometimes referred to as *gifts* of nature. Ecosystem services are simply defined as "the benefits people obtain from ecosystems". Forest ecosystems in particular provide a wide range of services, including some tangible and traded items sometimes referred to as 'goods'. Elaborations of the different sub-divisions of the ecosystem services are as follows:

- Provisioning services are material items for direct or near-direct human use. Examples are crops, forage, livestock, wild-caught fish or animals, fresh water, timber, fuel and fibre.
- Regulating services keep the flow of other ecosystem services within a desired range, and prevent ecosystem "disservices" such as natural disasters from getting out of hand. They include services such as pollination, climate regulation, flood attenuation, air and water quality maintenance and pest regulation.
- Cultural services make the world a place in which people want to live. They include amenities and recreation, aesthetic and artistic appreciation, educational and scientific benefits, spiritual inspiration and sense of place.
- Supporting services are the underlying ecosystem processes that allow provisioning, regulating and cultural services to be provided, including the preservation of options. They include such services as net primary production, habitat for biodiversity, soil formation and the cycling of nutrients.

was moderated, the inherent inability of natural forests to produce enough wood; aggravated by unprecedented rise in human population of Uganda from 4 million in 1950s to over 10 million in 1970s natural forests would still have succumbed way back in 1980s. Now everybody knows of course that Uganda is using and/or destroying her forests at a fantastic rate. The only course of action that was available to the earlier foresters was to make wood outside the natural forests. Theoretically, they argued that individual timber species which could yield 15-30m^3ha^{-1} yr^{-1} could be grown in plantation on the 300,000ha of grassland which formed part of the government Forest Reserves. Certainly producing wood outside the natural forests within a reasonable time frame was a brilliant idea that was meant to 'buy' millions of hectares from the natural forests and woodlands which would have to be logged to supply timber for the market. Soon after this realization, Uganda began to look for elite planting materials to fulfill the dream through plantation forestry.

CHAPTER TWO: Germplasm for Plantation Forestry

2.1 Early planting

Historically, the research to select suitable species for planting in Uganda started in 1908 and records show that to-date more than 170 species of trees have been evaluated in about 400 research plots scattered throughout the country. Pieces of evidence available from the pre-independence FD annual reports indicate that the history of plantation forestry of Uganda can be divided into three eras. The first era was the pole-fuelwood plantation that was dominated by *Eucalyptus*, cassia (*Cassia siamea*) and nsambya (*Markhamia platycalyx*). This was followed by the plantation forestry of desirable indigenous timber species like mahogany, mvule, musizi or nkoba and the third era that was characterized by planting exotic softwood conifers and elite eucalypts for timber. Pole-fuelwood species were planted in small woodlots in the vicinity of county and sub-county headquarters.

Silvicultural research designed for recruiting indigenous trees into plantation forestry began with many indigenous species. In particular *Entandophragma angolense, E. cylindricum, E. utile, Khaya anthotheca, K. grandifolila, Fagara leprieurii, Lovoa trichilioides, Albizia zygia, Blighia unijugata, Maesopsis eminii, Chlorophora (Milicia) excels, Piptadenistrum africanum, Trichilia prieuriana, Celtis mildbraedii, Cola giguntea* and *Ficus mucuso* were tested for their suitability for plantation development (Karani 1993). Results reported from the trials in Mpanga Forest Reserve were encouraging but a combination of slow growth rates and pests militated against their adoption. For example, during this early search, two desirable species: mvule (*Melissia excels*) and mahogany (*Entadophragma*, *Swientenia* and *Cedrella* spp.) which stood out well were unfortunately attacked by a psyllid, *Phytolama lata* (mvule) and the mahogany shoot borer, *Hypsipyla grandella* (meliaceous species). Severe insect pest attacks caused stunting of the young and/or saplings and as such reduced growth of the trees. Out of pole-fuelwood species, eucalypts have persisted to-date while practically all the indigenous species were abandoned because of their slow and low productivity as mentioned earlier. Failure of plantation forestry

These brief and extensive evaluations culminated into the choice of 5 plantation species. Cypress (*Cupressus lusitanica*) whose timber was designated for shuttering concrete works, *Pinus patuala* and *Pinus radiata* were assigned to the moist highlands while *Pinus caribaea* and *Pinus oocarpa* were for planting in the lowland savannah woodland reserves. For the highland species, site-specificity was of paramount importance. Cypress was recommended for planting on the lower slopes and valley bottoms which are characterized by deeper soils while pines were expected to do well on the upper slopes and ridges where the soils are dry and rocky.

Technically, although the siting of conifer plantations was pure accidental (Epila-Otara 2013), the choice of species for the development of any of the conifer plantation blocks was governed by altitude, climate, soil type and availability of planting materias. Thus for example, in an apparent belief that upland conditions were favourable for cultivating exotic conifers, the *C. lusitanica* and *C. benthamii* being the first species to be introduced into Uganda (Dale; 1954, FD; 1957 and Leuchars; 1960) were in general planted at high altitude locations of Mafuga, Lendu, Kapkwata and Suam. Patula pine was planted on the ridges and shallow soils where *C. lusitanica/benthamii* complex was poor performer. On the lowlands, *P. caribaea* was found to be able to withstand the desiccating effects of the dry seasons. Strictly speaking, a single species of conifer was planted in pure stand which as you will remember was an equivalent of about five to ten fire control unitss important to note that this strategy did not rule out the possibility of planting more than one species of conifer side by side within a single compartment thus in essence creating a spatiotemprally mixed stands which in the long run led to conifer crops of varying ages and species co-occurring within one compartment.

Historical development of conifer plantation forestry was given by Kingston (1969) that: *'Softwood planting began at Mafuga, in 1941 on a trial scale and was expanded to a field scale in 1946. Other schemes, mainly in the west of the country, were opened at Kyehara in 1948 and Lendu in 1949...Initially planting was confined to the higher altitudes over 5000 feet and was mainly done with Cupressus benthami and Cupressus lusitanica. Gradually however emphasis changed and Pinus spp – mainly P. patula – were more favoured and as planting crept to lower elevations a wide variety of other Pinus spp were planted with P. caribaea dominating. Thus by about 1967/68 there were about 4500 acres of Cypress mainly in the older age grouping and 11,000 acres of Pines with the proportion of Pines increasing with every year planting...'* Earlier on, Kriek (1967) noted that the following species could be used for plantation development in Mafuga: *Pinus taeda, P. pseudostrobus, P montezumae and P. leiophylla.*

Lastly, it is important to mention here that at the peak of conifer plantation development, the annual planting targets for the working plan areas (WPA) were huge: for example, the five year development plan of 1971-1976 put the annual planting target at 2000 ha. In the case of Lendu WPA the annual target under the NORAD scheme was 80 ha and this was the last target planted in 1975 at Lendu and Okavu-reru. Unfortunately with the exodus of Norwegian staff planting targets in all WPAs began to decline and eventually stopped in 1982.

Established using 9-12 month old seedlings under a taungya system, variable rotation ages were anticipated: first foresters thought that both the conifers and cypress needed to grow for 35-40 years to attain the final crops with a mean diameter over bark of 45 cm. However, in the 1970s,

Characterized by two successive earlier introductions of fresh Eucalyptus germplasm from different sources, Uganda has had a long history of growing eucalypts. As hinted earlier, the first introduction which dates back to 1912 was motivated by the desire for fuelwood for the steam engines of the Uganda Railway and mosquito plantations in peri-urban areas. Purposely, mosquito plantations of eucalypts were designed to drain and degrade the breeding sites of the mosquitoes: those swamps close to human settlements. Obviously, this intervention was intended to lower mosquito populations and hence reduced the occurrence of malaria among the human populations. But as it turned out this technology was a scientific fallacy because eucalypts just like any living plants can only take amount of water that is useful to them – excess stagnant swamp water became harmful. Thus instead the excessive swamp waters killed the trees in the long run. Debate on water use by eucalypts has remained confused partly because of such early misuse of science promoted by the foresters themselves!

The second wave of introduction of eucalypts to Uganda was driven by the demand for industrial wood. We have just seen that much as natural forests of Uganda were not degraded even as late as 1960s, experts had estimated that because of their small MAI natural forests of Uganda could not have sustained the multiple demands for wood in the near future. Fifty two species from the genus *Eucalyptus*; some of which had already performed very well for over 70 years in South Africa were targeted. Using the same criteria like in conifers four *Eucalyptus* plantation species were selected, two: *Eucalyptus grandis* and *E. saligna* are now grown in the moist southern parts of Uganda and *E. cameldulensis* and *E. tereticornis* are grown in the relatively arid northern parts of the country. Apart from the strong affinity of *grandis* and *saligna to* hybridize in the wild, no attempts have been made to improve the poor quality of the eucalypts, especially the dryland species. In particular, the two dryland eucalypts are slow growers; with *E. cameldulensis* having the worst stem form. However, unlike the conifers the original crops of the four major Eucalyptus species that were promoted for plantation development never suffered serious insect pest attacks except the termites at the time of planting in the drylands of northeast and northern Uganda. Today eucalypts grown in plantations, fire lines, windbreaks, woodlots, boundary plantings or in groves are now an integral part of many rural landscapes in Uganda.

2.4 Manmade gap

Based on the yield table for *P. patula*, Kingston (1970) stated 'The F.D. is in a position to supply the whole of Uganda's demand for softwood timber provided that consumers will accept an increasing amount of *Pinus patula*'. Similarly, having constructed the preliminary yield table for cypress Kingston and Kaumi (1972) reiterated the same scenario; namely that economic rotations of 20-25 years for conifers would provide a plentiful supply of final crops from which the sizes of boards in greatest demand could be cut. Both conclusions were of course based on the fact that the country's 300,000 hectares of grassland reserves could be converted to softwood plantations. It is important to note that unlike Agriculture, the establishment and managing of forest plantations in Uganda was exclusively done by FD. Undoubtedly this strategy created serious drawbacks in the national tree plantation development.

from the outset that the national perceptions of any country vary with issues at hand but that all the variants of national perceptions require specific platforms. And so we began by formulating a platform on which to examine forestry issues by assuming that the word perception in this context broadly means an act of value judgment – in reference to economic, biological or spiritual dimension.

Expanding on this platform leads directly to a more defined form of human behavior towards natural resources which can best be described using the metaphor of biological survival; namely that the challenges man goes through to acquire essential resources for *'living today'* defines the values human beings attach to these requisite resources. In essence, this metaphor means that the philosophy of our *short term-survival* dictates humans to assign values to resources which are essential to their survival according to the relative availability of these resources: scarce resources which are naturally difficult to acquire are valued highly compared to the plentiful and readily available ones – *these latter resources are usually branded 'gifts' of God*: the attitudinal mind set which often leads to unmitigated utilization of such resources up to the point of the 'tragedy of the commons'. It is therefore a combination of these economic, biological and spiritual realities coupled with lack of awareness of the inter-connectedness of forest ecosystem functions to the production of their most valued resources – water, food crops and animals that formed the basis of past and present conception Ugandans hold on forestry. Essentially, it is indeed the understanding of shifts in the economic and biological paradigms which can help us to gauge the current perception of Ugandans on forests and trees.

Earlier in section 1.2 we noted that the data on forest loss, without any doubt, tell us that for a long time (Karani 1993) wood in Uganda have been one of the most critical resources that are exploited by the majority of the rural poor and yet its production attracted very little inputs from Government of Uganda. Thus based on the concept of resource acquisition expounded above, low investment in forestry leads us to a single conclusion namely that because in the past forest resources were abundant, government and users assigned very little values to them. Throughout the past 50 years of post-independence administration, gradual but steady acceptance of forest as a vital resource characterized this primary industry. Then the wood scarcity (*rarity of wood*) resulting from a combination of manmade gap in plantation forestry (section 2.4) and wanton destruction of natural forests (section 1.2) propelled forestry into the lime light. Similarly, the expulsion of Asians in 1972 which accidentally exposed Ugandans to the lucrative business of timber processing and trade motivated local people to invest in tree growing. Before this economic shift, the value of forest products remained hidden within the Asian community. Both occasions marked the beginning of change of attitude towards forest resources; which was later underpinned in 1987 through the introduction of agroforestry in which tree growing was taken back into the treeless farmlands of Uganda.

Indeed as stated earlier, unlike in the past observations show that if assisted many rural people are now willing to grow trees for domestic use and income generation at household level. Indeed as more people discover the values of forest products and services the perception of Ugandans on

Africa. Transfer of the mature clones which were ready for evaluation in the field trial was done on two separate occasions as described in section 3.4.

Indeed as hinted at above, the tree biotechnology project of Uganda (TBP-U) was technically demand driven and the overall objective was to improve the living standards of the rural communities in Uganda who as we saw earlier were now ready to grow trees; particularly of the resource poor segment of the population by enhancing forestry production. The following specific objectives guided the introduction and implementation of TBP-U:

- To transfer and apply in Uganda tissue culture and clonal forestry biotechnology by transferring superior proprietary Eucalyptus clones from Mondi Forests Limited, and growing them for field evaluation trials and demonstrations, test their performance and monitor environmental adaptation and suitability.
- To establish large-scale clonal seedling production in Uganda through private sector involvement for Eucalyptus clones from South Africa.
- To select and utilize Ugandan tree biodiversity with economic value for forestry and agroforestry through clonal tree technology, learning from the Eucalyptus model from South Africa and Kenya, through public and private inter-phase activities for sustainable environmeny and niche markets.
- To build the capacity in tissue culture and clonal forestry technology in Uganda that would expand creating new opportunities, jobs and encourage entrepreneurship in rural and urban environments.

3.3 Formulation and management

Four institutions were pivotal in formulating the proposal, funding, selecting, introducing and implementing TBP-U: namely, the National Agricultural Research Organization of Uganda, International Service for the Acquisition of Agri-biotech Applications (ISAAA) *Afri*Center, Kenya, Gatsby Charitable Foundation (GCF) of UK and Mondi Forests Limited of South Africa. Undoubtedly, the experience of a similar tree biotechnology project in Kenya (TPB-K) motivated and inspired TBP-U in several ways. For example, TBP-K results from the clonal trials that was conducted between 1997 and 1999 showed that the clones performed exceptionally well in marginal areas like Machakos by attaining 100% survival rate with record top height of 6 m within one year after planting. And on top this rapid growth there were no incidents of pests and diseases: not even the termites which in Uganda can cause significant losses. Follow-up and backstopping by the Mondi scientists and regional collaboration played a major role in shaping the planning, implementation and evaluation of TBP-U.

Drawing from the experiences of both ISAAA and TBP-K, the staff of NaFORRI headed by Dr James S. Epila-Otara wrote the proposal for the project. Similarly, because of her vast experience of brokering TBP-K project proposal, TBP-U also requested ISAAA to broker the clonal forestry transfer and applications which had already demonstrated positive commercial impacts in South Africa and Brazil. Finally, TBP-U document was submitted for funding to GCF in close

various aspects of forestry in Uganda including a document on plan for modernization of agriculture (PMA) were also availed to the scientists by NaFORRI.

Mondi scientists never documented their personal perceptions on Uganda when they paid this visit. Nevertheless, the basic physical and climatic features of Uganda which the scientists experienced were extensively described by Gakwandi (1999). In summary, Uganda is located at the heart of the great African plateau that rolls from Ethiopia to southern Africa. Except for depressions within the basins of Lakes Kyoga and Albert where land falls to 600m, the average altitude of Uganda is1000m above sea level. Similarly, apart from the Karamoja sub-region with annual rainfall of about 750mm, Uganda's annual rainfall which is punctuated by the dry spell of June-July ranges from 1000-1500mm. The soils of Uganda vary greatly but they are generally deep and red in colour. Both the soil characteristic and good rainfall distribution provide a wide range of silvicultural possibilities as described by Jacovelli *et al.* (nd).

The NaFORRI staff familiarization with clonal technology which also needed to be accomplished before the clones were introduced to Uganda was done in 2001. This was necessary because prior to the advent of TBP-U, clonal forestry had never been on the research programme of NaFORRI. Thus as a head-start in the implementation process of TBP-U, it was recommended that the project leader had to undergo a short, hands-on training in clonal technology in South Africa. Dr Epila-Otara in his capacity as the project leader spent two weeks at Kwabonambi clonal nursery learning the basics of clonal research and production as well as clonal plantation establishment and management. Kwabonambi exposure introduced the project leader to the jargons of clonal forestry and how clones are bred and mass-produced at the nursery. Later, Moses Basoga, the technician attached to TBP-U was also trained in clonal technology in Karura and Kwabonambi nurseries of Kenya and South Africa respectively. Thus, when the selected clones were air-freighted into Uganda as described below, NaFORRI was ready to implement TBP-U.

3.5 Transfer of clones

Clonal transfer which involved eleven hybrid and one pure (TAG 5) clones from South Africa to Uganda in 2002 marked the third introduction of Eucalyptus resources. Indeed, as alluded to earlier this third introduction was motivated by the need to bridge quickly an approximate 30-year- manmade gap in the national wood production which began during the military regime of the 1970s. Broadly, the hybrid clones of Eucalyptus were selected on their strength for fast growth resulting from hybrid vigour, excellent stem form, resistance to diseases and good environmental plasticity. Presumably the data and information from the fact-finding visit coupled with their unrivaled experience in clonal forestry enabled the Mondi scientists to select twelve candidate clones which they thought would do well in Uganda. It is important to note that out of the twelve clones only one: GC 796 had also been given to TBP-K. The rest: GC 514, GC 540, GC 550, GC 578, GC 784, GU 7, GU 8, GU 21, GU 607, GU 609 and TAG 5 given to TBP-U were unique to TBP-U. The GC hybrids are crosses between *Eucalyptus grandis* and *Eucalyptus cameldulensis* while the GU hybrids are from crossing *E. grandis* with *Eucalyptus urophylla.* TAG 5 is a pure *E. grandis* that was specifically bred for the Transvaal area of South Africa.

because the participating stakeholders demanded the practice. Otherwise trials were weeded twice in year one and two before the canopy closure reduced weed problem in the subsequent years.

Clones tend to be site-specific and thus trials for matching them to suitable places were deliberately sited in eleven agro-ecological zones of Uganda (Fig.2). Trials established in March-May of 2002 were sited on the public lands which belonged to the NARO institutions. The second set of eight trials was cited on private landholdings because of the poor experience we had with the four trials set on public land at Ikulwe, Serere, Ngeta and Abi. In the first place the trials at these sites were not looked after by the resident NARO staff that also had their work load to do on a day to day basis. Secondly the trials were vandalized: the local farmers grazed their livestock at the trial sites within the first year thus destroying young plants and the barbed wire used for fencing the trials were stolen. Later as the trial matured, the trees were stolen by the local people. Thus to avoid similar difficulties, trials at Apala, Akol, Kumi, Masindi, Sembabule, Bugonzi, Ntungamo and Kabale were established on private land. And the memorandum of understanding (MoU) signed by the land owners allowed NaFORRI to access and collect data from the trials for seven years after which the land owners assumed full ownership of the trees. In Kabarole district where private land could not be acquired, the trial at Kyemboga was mismanaged. And because of war the trial established at Katakwi to test the response of the clones under the arid conditions of the northeastern Uganda was not well managed by the farmer.

Four replicates were used to investigate the response of the twelve clones to the growth conditions at each of these sites, with site-specific land race seedlings as controls (Fig. 4). Oriented along the contour as mentioned above, trial sites, each measuring 100 x 100m were ploughed and harrowed respectively on various dates in March and early April of 2002 and 2003. Because of the steep terrain Kabale site was hand hoed once before establishing the trial. Termite mounds within and those adjacent to the trial sites were poisoned with Regent 3G to kill the termites which are known to cause up to 100% damage to young eucalypt plants. Poisoning of the termite mounds followed the manufacturer's recommendation. Experimental design (Fig. 4) in which four borderless blocks each having all the 12 clones and control seedlings randomly assigned in 4 x 4 tree plots, was pegged out on the ground. On the day of establishing trial 5 persons working ahead of the planting crew dug 2.5 x 2.5m planting holes which were immediately poisoned with a predetermined dosage of Regent 3G sprinkled on the excavated soil. Using razor blades, a crew of 10 people freed the well watered clonal plants from the plastic pots, planted them individually and back-filled the holes with the poisoned soil to protect the plants from termite attack was. Trials at Ngeta and Bugongi were inter-cropped with groundnuts and millet respectively (Fig. 5), but others were weeded twice before canopy closed. Barbed wire was used to fence out human and livestock in all the trials.

4.1.2 Sampling and parameters

GC 796	58	89	81	100	93	69	63	83	97	92	97	89
Control	56	89	64	97	89	56	70	72	78	70	78	72
GC 540	50	100	97	100	100	89	89	94	97	89	100	100
GU 21	47	94	94	97	96	75	85	89	86	64	100	92
GC 784	47	97	86	100	89	78	85	100	94	69	100	97
GC 578	47	92	97	86	89	75	48	64	92	97	92	100
GU 7	22	89	75	100	85	61	33	67	86	100	100	83
TAG 5	8	69	73	89	85	39	22	44	64	86	86	83
GU 607	8	86	69	86	93	3	67	14	86	69	100	67
GU 8	6	94	83	94	93	64	63	58	86	83	94	94
GU 609	0	86	72	81	81	6	33	22	61	75	83	72

For example, the closely related GU 607 and GU 609 crushed at Ngeta, Akol and Mukongoro, while at Apala only GU 609 was susceptible. On the other hand, GU 7 and GU 8, which did so well in the southern and western Uganda, were dangerously vulnerable at Akol and Apala as implied in the samples sizes. Tag 5, the pure *E. grandis* was obviously misplaced in the north and east of Uganda as they died in large numbers. Massive clonal mortalities occurred during the prolonged drought of 2004 (Epila-Otara, unpubl. data). In a way, their reaction to the drought conditions was a blessing because previously, these clones stood the test of the annual dry season prevailing in the trial areas. By succumbing to the severe drought of 2006 the clones truly gave us the opportunity to observe their susceptibility to drought, which otherwise would have passed un-noticed. Selective susceptibility of the *urophylla*-hybrids to northern and eastern conditions compared to the *cameldulensis*-hybrids was probably associated with the shallow rooting characteristics of *E. urophylla* (Lugo and Francis 1990).

4.1.4 Height, dbh and volume

Impressive uniform stem forms, self-pruning and branching habits of the clones showed little variations with locations. Clones GC 578, GC 796, GU 8 and GU 7 produced trees with very straight stems compared to GC 540, GC 784, GU 21, GU 609, TAG 5 and the landraces in that order. Summary of the frequencies indicated that GC 540, GC 550, GC 578, GU 7 and GU 8 had the highest percentage of small branches in all the sites while the landraces and GU 607 at Akol, Mukongoro and Serere produced big branches. Curiously, the apical third of the stems of the GC 550 trees at Ngeta, Serere, Ikulwe and Nyabushabi were 'snaking': the characteristic that disappeared with age, and thus appeared to be a symptom of the fast growth rate of this particular clone.

Nge	0.4	0.7	0.7	0.3	0.8	0.4	0.3	0.3	0.4	0.4	0.3	0.5	0.4	4
Ser	0.3	0.5	0.4	0.2	0.4	0.3	0.3	0.2	0.3	0.2	0.2	0.3	0.2	4
Ako	0.1	0.1	0.1	<0.1	0.1	0.1	0.1	0.1	0.1	<0.1	-	<0.1	0.1	11
Apa.	0.1	0.2	0.2	0.1	0.2	0.1	0.1	0.1	0.2	0.1	0.1	<0.1	0.2	12
Bug	0.3	0.4	0.4	0.1	0.3	0.2	0.2	0.2	0.3	0.3	0.3	0.2	0.2	5
Kat	0.1	0.2	0.2	0.1	0.2	0.1	0.1	0.2	0.1	0.1	0.1	0.1	0.1	8
Kig	0.3	0.3	0.3	0.1	0.3	0.2	0.2	0.3	0.3	0.2	0.2	0.2	0.2	6
Muk	0.3	0.2	0.3	0.1	0.2	0.2	0.2	0.2	0.2	0.1	0.1	0.1	0.1	4
Nya	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	11

Trend in girth sizes was reflected in the average volumes of the clones because ranking by volumes showed that *camadulensis*-based clones indeed grew more rapidly (Table 4). It is of course not easy to discern from Table 4 that only the height and dbh, and not necessarily together with stem form, were the best indicators of volumes in clones. Tall clones with big girths but slight crook in their stems such as GC 540, GC 550 and GU 21 had yielded large amounts of wood compared to tall, straight-boled but slim clones like GC 578, GC 796, GU 7 and GU 8. Ikulwe, Ngeta and Kifu sites were impressive in two outstanding clones: GC 540 and GC 550 which registered growths that yielded over one-half cubic meters of wood within 4 years (Table 4). Only GC 540 yield at Abi was comparable to its counterpart in Ikulwe, Kifu and Ngeta. It is not easy to explain the remarkable growth performance of GC 514 at Ikulwe and Kifu (Table 4). Serere trees were stunted for their age as all of them yielded low volumes compared to Ikulwe, Kifu, Ngeta and Abi. Among the second cohort trials volume ranking was in the following ascending order: Akol, Nyabushabi, Katooma, Apala, Mukongoro, Kigumba and Bugongi (Table 4). The only pure species clone, TAG 5 which was purposely bred for the cooler conditions of the Transvaal, South Africa (Neville Denison, personal comm.) never performed well in drier sites compared to Ikulwe, Kifu, Ngeta, Kigumba and Bugongi (Table 4).

CHAPTER 5: Identifying Eucalyptus clones for plantation development in Uganda

5.1 Selection of clones

Using the strategically sited trials, NaFORRI was able to demonstrate that Eucalyptus clonal hybrids sourced from a South African company, Mondi Forests Ltd can produce fuel wood within 2-3 years and timber within 15 years. Besides, data collected from all over Uganda show that these clones withstand drought reasonably well. Not only that in the course of implementing the Phase I of this project, NaFORRI had also borrowed TBP-K and perfected a simple nursery technology – the tunneling technique to enable nurserymen with basic education produce their

6.1 Infrastructure and capacity building

Implementation of TBP-U in Phase I as described above targeted the objective one which is stated in section 3.2. Nevertheless, in order to facilitate the implementation of the subsequent objectives of TBP-U as stated in section 6.2 below, the construction of the clonal nursery infrastructure and human capacity building were brought forward and implemented in Phase I. Nursery site that measured approximately 30 x 210m was the first infrastructure constructed at the headquarters of NaFORRI, Kifu. Kifu Nursery was divided into two parts: the biological and irrigation units as described in the Annual Report 2004 of the TBP-U (Epila-Otara2003). Modest pump house which draws water from the reservoir constructed uphill to allow for gravity feeding, was designed to irrigate the freshly placed cuttings and the rooted plantlets both inside the rooting house and outdoors at the grow-out section. Construction of the cutting shed, office, pump house and ablution block with provision for males and females were completed during Phase I. Similarly, by the end of Phase I the clonal hedges established with left over plants imported from Mondi Forests Limited in 2002 and 2003 were all in production. As mentioned in section 3.4, two staff members of NaFORRI who were directly responsible for the implementing Phase I of TBP-U underwent hands-on training both in Kenya and South Africa.

6.2 Project renewal

By the design, this project was intended to be renewed upon the successful implementation of the first phase which addressed one of the four objectives; namely to transfer, evaluate the performance and monitor environmental adaptation and suitability superior proprietary Eucalyptus clones from Mondi Forests Limited in Uganda. Renewal of the project was meant to implement the rest of the remaining objectives in stages: first Phase II was to establish large-scale clonal seedling production in Uganda through private sector involvement; then followed by selection and utilization of the Ugandan tree biodiversity with economic value for forestry and agroforestry through clonal tree technology to enhance sustainable environment and niche markets and thirdly Phase II was also intended to implement the cross-cutting objective which sought to build the capacity in tissue culture and clonal forestry technology in Uganda.

Implementing U-TBP I took four years and was on schedule. Writing the renewal document took place in 2005 and involved key stakeholders: ISAAA was represented by its Director, Dr Samuel Wakhusama, Mondi Forests Ltd was represented by the late Errol Duncan, Dr John Aluma stood for NARO Secretariat, Paul Jacobeli represented the Sawlog Scheme, Isaac Kapalaga from NFA, and Mr. Ferdinand Mugisha stood for the tree-growers. Locked up in Ridar Hotel, Seeta, Mukono District, the writing task took one week and the document was largely ready for cleaning and submission by NaFORRI. Three key features which characterized this request were: expansion of the Kifu Clonal Nursery which was established between 2002 and 2003 to the holding capacity of 40,000 ramets which the calculation based on the experience from Mondi, Kenya and Kifu showed could meet an annual production of about 1,000,000 plantlets, establishment of 4 Regional Holding Nurseries in which clonal plantlets produced centrally at

Without the basic skill but with full inheritance of the infrastructure and resources that NaFORRI had developed in Phase I, the leadership of GCTP was from the start bound to make many mistakes. Indeed as a matter of fact, the focus of Phase II of TBP-U became money and profit based on false data inputs. Later, the bottom line then shifted to mass production of seedlings for profit even if NaFORRI had not recommended the clone for commerce: the case in point is the massive production of 'sprinter' clones (Hulett et al. 2004) like GC 578 which research had showed to root and grow quite well but became stunted within the first two years after planting and there after never grew like the so-called 'stayers' (Hullet et al. 2004 and Epila-Otara and Ndhokero 2009). It is possible that this desire may have forced nurserymen to use branches of the cuttings to increase production of plantlets to meet the set targets. Indeed with the entry in 2013 of the new investor, Tree Resources Ltd (TRL), fraud may be enhanced beyond repair. Of course it is stated position that NaFORRI should not be held responsible for the fraud and indeed the breach of Contract Agreement which NARO signed with Mondi Forests Ltd in 2001.

Documented data from Phase II of TBP-U are not readily available and this has impaired NaFORRI's ability to evaluate objectively the successes and/or failures during Phase II of this remarkable project. But based on the well established biology of ramet productivity that the NaFORRI writing team used, dismissing the minimum 40,000 ramets for Kifu simply meant that GCTP failed to achieve the annual target of 1,000,000 cuttings which based on the sale price of 400 shillings per plantlet, enabled the enterprise to break even. Earlier data which GCTP shared with NaFORRI consistently showed that TBP-U Phase II was heading for failure.

6.2.2 Unfounded cricticsms

With the Gatsby rejection, a torrent of criticisms was leveled against NaFORRI: the consultancy report by Hardcastle and Evans (2009) epitomized the hopelessness of these criticisms. GCTP and Sawlog Promotion Grant Scheme (SPGS e.g. Jacovelli et al. 2009 stole the NaFORRI data which they used for construction the silvicutural sites) including ISAAA (photograph on the cover of the conference report by Hulett et al. 2004) used NaFORRI data in one way or another. Even Hardcastle and Evans (2009) graced the cover of their consultancy report with the picture of NaFORRI trial at Ikulwe. Undoubtedly, Hardcastle and Evans (2009) were misled by Kilimo Trust management and Gatsby who failed to draw their attention to well documented evidence of how NaFORRI implemented Phase I of TBP-U. As if they were worried about this inadequacy Hardcastle and Evans (2009) confessed to this omission in their disclaimer and limitations thus *"...Information was collected through discussion and from the literature made available to the team by Laurence Cockroft in advance of the visit. We were not given, and have not therefore reviewed, complete sets of information such as Annual Reports, nor did we have access to all reports on and analyses of activities. The comments and conclusions drawn are made on the basis of the sample reports and publications made available to us together with field visits and discussions".*

CHAPTURE 7. Post-Kilimo research efforts

7.1 Wood properties

Clonal eucalypts developed in South Africa for pulping were introduced to Uganda primarily for supply of fuelwood (Epila-Otara, 2004a). However, all along it had not been clear whether these clones would fulfill the intended objective for which they were introduced. Highlights on wood properties reported here are extracted from the study by Turinawe et al. (2013) who investigated the density, calorific value and cleavage resistance parallel to the grain of the most widely adopted hybrid clones: GU7, GU8, GC540, GC550 and GC796. Values of these parameters were compared with published data on pure species of *E. grandis, E. camaldulensis* and *E. urophyla.*

Investigation has shown that the basic density of all clones ranged from 550-735 Kg/m3. GC540 had the highest mean basic density (664 Kg/m3) while GC550 had the lowest (627 Kg/m3). Calorific value for the test clones ranged from 10223-25377 KJ/Kg; with GU7 and GC796 having respectively the highest (17800KJ/Kg) and lowest (16700 KJ/Kg) calorific values. Cleavage resistance ranged between 8 and 30 N/mm. Again GU7 together with GC540 had higher mean values for cleavage resistance [20N/mm] than the other clones. Although clonal wood had lower CV than parent materials, clonal timber at 6-7 years remains a viable alternative for fuel wood to parent materials since the differences in CV can be compensated by the superior volume increment of clones per unit time and better CLR values to facilitate better splitting especially of GC clones. This should be considered as important in Uganda and those other countries which rely heavily on fuelwood for energy.

Wood of the same hybrid clones was tested for suitability in the common engineering applications in construction industry, furniture and transmission poles. Using specially prepared wood samples the maximum compression strength parallel to the grain (MCS), maximum shear strength parallel to the grain (MSS) and static bending strength perpendicular to the grain [namely the Modulus of Elasticity (MOE), Modulus of Rapture (MOR) and Work to Maximum Load (Wmax)] of GU7, GU8, GC540, GC550 and GC796 were investigated. Similarly, results were compared to the published data from *E. grandis, E.cammaldulensis* and *E. urophylla.* Tests revealed that the mean values for MCS, MOR and MSS were high in clones GC540 [84 N/mm^2, 153 N/mm^2, 12 N/mm^2], GC796 [74 N/mm^2, 148 N/mm^2, 12 N/mm^2] and GU7 [67 N/mm^2, 139 N/mm^2, 12 N/mm^2] indicating both strength and better workability. GC550 had the lowest mean values for all properties tested and yet greater MSS compared to parent materials indicating better workability. Modulus of elasticity (MOE) of all clones tested was lower than that of parent species (Table 5) indicating potential weakness in bending.

Table 5. Comparison of wood properties of clones and parent species [MCS=Maximum compression strength parallel to the grain MSS=Maximum shear stress parallel to the grain, MOE= Modulus of Elasticity, MOR= Modulus of Rapture, Wmax= Work to maximum load and * sourced from PROTA].

Physical properties	Hybrid clones	Parent species *

combination of superior growth conditions e.g. soil fertility at a given site, better acclimatization and possible natural hybridization of the Eucalyptus species that have been introduced into the country. Both of the last two attributes should be exploited in the national tree improvement programme. Variation in response within the group of the *cameldulensis*-based clones appears to be the function of how much of the parental attributes was inherited: higher dose of cameldulensis attributes enhanced the performance of the clones in drier areas and conversely grandis attributes promoted the rapid volume increment in the north.

8.2 Environmental plasticity

It is unclear why the *urophylla*-based clones failed in middle north and yet *E. urophylla* is comparatively more tropical than *E. cameldulensis*. Shallow rooting remains a credible reason because prior to the onset of 2004 drought GUs showed very little sign of environmental stresses. And yet three weeks into the drought the GUs in Ngeta and Apala began to die in large numbers. Massive mortality among the GUs at Akol was quite incomprehensible given that this trial site is less than one hundred meters from the shore of Lake Kwania. Occurrence of excessively deleterious environmental conditions such as was witnessed in the middle north is important because it availed the rare opportunity to subject the foreign clones to the ultimate possible stress. In other words, had it not been for the severe drought that brought out the vulnerability of the apparently (Lugo and Francis 1990) shallow-rooted GUs, some of them might have been selected falsely for developing plantation in the Kyoga peninsular. Data accruing from such responses add rigour with which farmers would be advised.

Environmental plasticity exhibited by the selected clones is of immense value in the economics of mass production which is necessary for plantation development. But there are three technical questions that need to be addressed urgently: rooting, silviculture and wood quality of the clones. Definitely, the silvicultural practices that have been developed for pure Eucalyptus in Uganda will not work because clones by design produce uniform trees that self-prune in time. This means that farmers do not have to practice both thinning and pruning in their plantations: the challenge to research establishment therefore is to find the best spacing that will allow the trees to grow to full rotation without thinning nor pruning. Similarly, whereas it was alluded to earlier that the critical criterion for selection of clones was the yield performance, the physical quality of the wood is equally important especially in so far as the clones would be grown for timber. Rooting ability was not considered in the selection of the five clones and yet it is the most critical criterion in the production of clonal material for planting. Last but not least, it is hereby recommended that the final assessment due at age seven (Neville Denison personal comm.) should be conducted and the data used to revise the list of the current selection of the clones revised accordingly.

8.3 Selection criteria

- Rooting, silviculture and properties of the wood of the selected clones should be researched to enhance the impressive gains Uganda would get from growing Eucalyptus hybrids.
- Implementation of Phase II created a serious mistrust that almost ruined the South- South - North model of technology transfer.
- NaFORRI should not be held responsible for biological failure in the commercialization of TBP-U.

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