Nigerian Journal of Ecology 1 (1-12) 1999

AFFORESTATION AS A FORESTRY STRATEGY FOR REDUCING CARBON DIOXIDE EMISSION IN NIGERIA

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Greenhouse gas (GHG) emissions should be regulated for ecosystem and environmental stability. GHG reduction from the forestry point of view can be facilitated either through CO_2 sequestration, reduction in emission factors such as deforestation and other biotechnological control systems that limit air pollution. In this paper, the role of forestry in reducing carbon emission is outlined. Analysis of afforestation as a means of reducing the emission of carbon dioxide in Nigeria is carried out after highlighting other possible forestry options such as conservation, reforestation and improved harvesting and utilization technology. In order to meet the wood requirement for various uses in Nigeria, additional 12,000 ha of pulpwood plantation is required by the year 2000 rising to 29,000 ha in 2010. The pulpwood plantation, for ecological reasons, should generally be concentrated in the south. Pole and sawnwood production should be based in the south and the middle belt of the country to the tune of 0.85million ha. by the year 2000 and 1.8million ha in 2010. Fuelwood plantation establishment should be located in the middle. Belt and northern parts of the country to the tune of 7.4 million ha and 8.2million ha. in 2000 and 2010 respectively. The overall afforestation program will require 8.4 million ha in year 2000 rising to 9.9million ha. in 2010. It is expected that about 519million and 687 million tones of CO_2 will be sequestered from these plantations during the same period. It is suggested that while international support is required to embark on the afforestation programme, private and community participation should be encouraged. It is also suggested that the scheme should be supported by appropriate policy and legislative structure and should be directed towards ecological contribution rather than commercial forestry per se

INTRODUCTION

The Nigeria's forest wealth is characterised by a diversity of vegetation types and microclimates contributing to environmental stability. With the on-going debate on global environment and climate change, the need for conservation of forest resources enjoys worldwide attention. The ecological role of forests in maintaining climate, locally through hydrological cycle and globally through carbon cycle, acting as carbon sink and balancing carbon dioxide concentration in the atmosphere enjoy additional attention.

Global forests are estimated to contain 66% above-ground terrestrial carbon, 45% below-ground terrestrial carbon while accounting for about 90% of annual carbon-flux between the atmosphere and terrestrial ecosystem (Dixon, *et al* 1992).

The kinetics of terrestrial carbon have also been attributed to transformation from forests to other uses and vice versa and it has been estimated that one third of an anthropogenic CO2 emission occurs from the conversion of forest land to other uses (Houghton *et al* 1987).

Following the general Krebb cycle, Greenhouse gas (GHG) reduction into the atmosphere can be accomplished either by improving phyto-gaseous uptake or decreasing the emission technologically. It has been recognised that uncontrolled GHG emission is one of the greatest contributor to global warming.

In the millennia, societies encouraged social control on tree felling in ecologically sensitive areas and thus promoted forest conservation. However, the original perception of forest ecosystems serving a multiple of functions for satisfying diverse and vital human needs for air, water and food is gradually being eroded, giving way to forest serving mainly commercial timber production and establishment of cash crops. However, since trees have to be physiologically and ecologically matched to these diverse end-uses, the practice of timber exploitation, indifferent to ecological requirements and other basic needs cannot, even in theory, be an acceptable forestry model for the social objectives of sustainable management and conservation (Vandana et al (1985).

Forests provide the much needed reduction in GHG emission. However, deforestation for various purposes has continued to be a major obstacle to this basic role of the forests and consequently reduce GHG emission. The main concern then is how to reduce deforestation of tropical forests. The bulk of the tropical forests is located in developing countries and deforestation in these countries is a consequence of economic growth. Appeal to rural populace to conserve the remaining tropical forest, thus reducing deforestation is likely to have socio-economic consequences. This is because the local economy is tied directly or indirectly to the forest for agriculture, firewood and other 'minor' forest benefits.

Growing of biomass to sequester carbon dioxide has been seen as a means of reducing emission of Greenhouse gases (GHGs). Two fundamental issues in forestry options have been identified (Myers and Goreau, 1996). These are the need to protect the existing forests in order to decrease the rate of carbon discharge to the atmosphere and developing additional areas that would sequester carbon and thus offset some of the fossil fuels- related emission. However, no developing country is likely to undertake large-scale forestry project just for the purpose of sequestering carbon. Moreover, scarcity of capital, technical and biological problems may militate against growing biomass mainly to act as carbon sink in these countries. The developed countries which generate most of the GHGs should be made to pay for these carbon based forestry programmes meant to sequester carbon dioxide. It is therefore important to identify the appropriate forestry projects and their extent to enhance further financial implications. Previous study (Ojo and Ijalana, 1992) have analysed various possible forestry options in Nigeria. These are conservation, reforestation, afforestation, improved product harvesting and utilization. In spite of the potentials of all these options to conserve or sequester significant quantities of terrestrial carbon and to reduce GHG emission, afforestation option especially through agro-forestry practices has been considered the most viable option from economic feasibility point of view.

The objective of this paper therefore, is to determine the extent of afforestation needed for various uses based on the potential needs of the country. The paper estimates the extent and carbon implications of the plantation establishment needed to augment the supplies from existing forest estates in the country.

CONCERN FOR THE ENVIRONMENT AND VIABLE FORESTRY OPTIONS FOR GREENHOUSE GAS EMISSION

A prudent management of the environment is needed to enable it perform the function of life support, raw materials supply and waste assimilation capacity which provides conducive environment for human, plant and animals. By various accounts, enormous financial resources and manpower are needed for correcting ecological damage attributable to pollution, desertification, deforestation, loss of biodiversity, erosion and flooding among others.

In order to meet the wood requirements and other benefits from the forest and to manage the forest on sustainable basis, various approaches have been used in Nigeria. These options include forest conservation and protection, management of natural forest by various silvicultural means and afforestation for industrial and environmental purposes.

Forest conservation and protection.

Conservation as a management option helps to improve CO_2 sequestration. Conservation is a policy that seeks to strike a balance between consumption, income demands and ecological and environmental imperatives in exploitation of natural resources (Ciriancy -Warntrup, 1952). Conservation involves the exploitation of valuable natural endowments like the forest in such a way that they will serve us better and longer than they would otherwise. In essence, we do not conserve a resource by leaving it unused, rather, by making the best economic use of it (Aregbeyen 1992) as well as guaranteeing their use in perpetuity. The main duty of the Forest Department early in the century was to ensure that enough land was allocated in forestry. Though the target was 25% of the country's land, by 1930s when reservation was virtually completed in the south and 1980s in the north, only 10% could be achieved in about 840 forest reserves throughout the country. This covers an area of 100,000 km^2 in the 1980s. Unfortunately, deforestation for various purposes has continued to reduce this area to about 96,000 km^2 or 9.6% of 100,00 total land area by 1990.

One of the important methods of preserving the genetic diversity of the forest is in- situ conservation through the establishment of forest reserves, games reserve and National parks, Strict Nature Reserve (SNR) and Biosphere Reserves. As at 1991, there were 18 game reserves with a total area of 8023 km^2 while additional 13 others with an area of 10306 km2 were being proposed. There are at present, six national parks in the country with an area about 21600 km^2. There are also eight Strict Nature Reserves (SNRs). Unfortunately, six of them have been reported degraded (Ojo, 1995)

Reforestation

Reforestation option involves the management of the natural forest on sustained yield basis through uninterrupted regeneration after exploitation. It emphasizes the need for continuous forest cover. Because the tropical rainforest contains different species that are at different stages of maturity, harvesting of mature trees are expected to be controlled and carried out so that the matured trees can be harvested without unnecessary damage to the remaining trees.

Various management practices were pursued in Nigeria up to the 1960s. These include enrichment planting, the Walsh system and the tropical shelterwood system (TSS). The TSS was practised between 1944 and 1966. The abandonment of TSS had been attributed to the political and socio-economic situations during the time (Kio, 1978; Lowe, 1978). A modified version to encompass enrichment planting and TSS was suggested. Unfortunately, this was never put to practice (Ojo, 1990). The management of natural forest has since been a matter of *laissez faire* with forest officers blaming the disappearance of the remaining natural forest on population pressure and industrial demands. A major constraint to natural forest management is the non-revision of the existing forest management plans in the past 30 years for most of the forest reserves. This has led to unregulated exploitation and consequently, illegal activities within the forest estate. However, recent activities under the Tropical Forestry Action programme (TFAP) seem to emphasize the development of working plans for some of the forest reserves in the country.

Product Harvesting and Utilization

There are two problems associated with product harvesting and utilization. These are wastage during harvesting and during conversion. The current harvesting techniques result in damages to both the harvested trees and the residual trees. Presently, less than 50% of the felled tree is removed from the forest leaving the remaining half to rot. Most of the operators of over 1600 sawmills in the country have no formal training on saw maintenance and operations. This has led to high wastage resulting in less than 50% wood recovery from the sawmills (Alviar, 1983). There is therefore the need for adequate training of the saw doctors. Moreover, the use of sawmill wastes such as sawdust, wood splint and off cuts for other products like wood cement, block board and laminated products will go a long way to reducing these wastes. Reduction in wood waste will also result in less pressure on the forest.

Afforestation Programmes in Nigeria

The importance of plantation establishment has been appreciated in Nigeria as far back as 1911, when Taunya version of agroforestry system was employed in raising plantation in southern Nigeria. The economic growth associated with the Nigerian independence in 1960 necessitated the use of wood for various construction purposes. This led to increase in industrial wood demand. However, the High forest inventory (HFI) of the reserved forest of southern Nigeria between 1974 - 78 indicated that the existing high forest would not be able to cope with wood requirements in the country, hence, the need to intensify plantation establishment.

In order to meet internal wood supply, the export of unprocessed wood was banned in 1976. Also an annual forest plantation establishment of about 30,000ha annually in 1981 rising to 60,000ha in the year 2000 in the high forest zone and 6,00ha to 80,000ha annually in the savanna reserves over the same period was suggested by the Food Agricultural organization (Ball, 1978). Unfortunately, plantation establishment has slowed down drastically since 1986 to the extent that by 1990, there was only 216,000ha of plantation in Nigeria. The purpose of these plantations has been classified into industrial {168,009ha} and environmental (48,017) purposes, out of which *Gmelina arborea* alone was 89,377ha (FORMECU, 1990) Moreover, there has been virtually no new plantation since 1990.

In addition to the need to meet the internal wood demand, there is need to protect the country against desertification and hence the need for arid-zone afforestation programmes, in the northern part of the country, under which over 48,000ha of plantation has been established as environmental plantation projects.

METHODOLOGY

The Choice of species and location for afforestation programmes are based on the species that have been proved suitable for the set objectives based on the wood quality and the growth rate of the species. Thus, Gmelina arborea for pulpwood, *Azadiracta indica* (neem) and Eucalyptus for fuelwood, *Tectona grandis* (teak) and *Nauclea diderrichii* (Nauclea) for sawnwood and poles and *Entandrophragma* sp. (Entandrophragma) for veneer wood (Table 1). Estimation of wood deficit is based on the work of Ojo (1994) (Table 2). Wood demand of particular wood use type was based on per capita requirements (based on 1991National population figure). Wood supply on the other hand, was based on the extent of forest estate (in each state of the Federation), the wood volume estimate, mean annual increment and the deforestation rate (2.5% within forest reserve and 3.5% outside forest estate). The State or/and national balance was given as difference between supply and demand for respective wood use type. Afforestation location for a particular wood use is based on the geographical location where the wood type can best be raised and area of acute shortage. Thus pulpwood, sawnwood and veneer wood in the southern part of the country, poles in the middle belt and fuelwood in the northern part of the country (Table 1)

The required hectarage is based on the plantation mean annual increment (MAI) of 10m^3/year in the middle belt and the northern part of the country and 15m^3/year in the south for Gmelina and MAI of 5m^3 /year in the middle belt and in the northern part of the country and 10m^3 /year in the south for other plantation species (Ojo, 1994). Estimate of cost of afforestation is for the whole rotation period of each species and product type and standardised per hectare.

Estimation of carbon sequestration by participating species is based on two approaches·

(a) Based on the assumption that 50% of wood biomass is composed of carbon (Myers and Goreau, 1995)

(b) Using the BASIS and COPATH models (Makundi *et al, 1991)*. BASIS model calculates carbon uptake by different land use and species, utilising such parameters as wood density, biomass, carbon content of the wood and soil carbon content. COPATH on the other hand uses the result of BASIS and other factors as wood decay rate and rotation to calculate the carbon increment per species and cumulative carbon uptake up to rotation age.

RESULTS AND DISCUSSION

There is no doubt that the four highlighted options have potentials for reducing GHG emission either by directly reducing wood wastes, thus reducing GHG emission or by sequestering CO_2. However, because no developing country may be willing to establish large scale forestry establishment just for the purpose of sequestering CO_2, it is necessary also to tie such establishment to the production of required wood products. Afforestation option may well be the most likely option to economically justify such investment.

Afforestation programme under the GHG emission is meant to supplement the supply from existing forest estates in the country ,hence emphasis is placed on meeting wood supply shortfall for the different uses such as fuelwood, pulpwood, pole sawnwood and veneer wood. Of these, only the pulpwood can be met by the present afforestation programme up to year 2000.

The projected fuelwood supply indicates a deficit of 12 million m^3 and 25 million m^3 in the years 2000 and 2010 respectively. Also pole will experience 0.9 million m^2 and 1.58 million m^3 deficit in the year 2000 and 2010 respectively. This trend is similar for other wood types (Table 2). It is these deficits that are of interest in order to increase the potential of the existing forest estates in the country.

In the fuelwood scarcity area of the North, Neem (*Azadirachta indica*) and Eucalyptus spp. Plantations should be established to augment social needs and at the same time regulate GHG emission. For these purposes, 4.9 million hectare of Neem and 2.6milion hectare of Eucalyptus will be required to be planted by the year 2000 with the establishment cost of US$2399 million and US$1121 million respectively. By 2010, 5.4 million hectare of Neem and 27 million hectare plantations of Eucalyptus are planned for US$ 10604 million and US$5004 respectively.

To take care of industrial pole and timber supply, while making eco-stability advances, teak (Tectona grandis), *Nauclea diderichii* and mahogany like *Entandrophragma* spp. will be planted on continuous basis. Plantation requirement for Teak and Nauclea will each gulp US$436 million by the year 2000 and US$3628 million by 2010. Mahogany plantation will require US$ 101 million to raise 87,000 ha by 2000 A.D and US$767 to raise 156,000 ha by 2010 (Tables 3 and 4).

Current *Gmelina arborea* pulpwood supply balances projected industrial demand up until the year 2000. More areas of Gmelina plantations is ecologically justifiable for GHG emission reduction strategies, but such effort could only be economically and socially acceptable beyond 2000 A. D. thus, supplementary Gmelina plantation of about 29.000 ha is recommended for the year 2010. US$144 million will be needed for this purpose. It is expected that from these afforestation programmes, 519 million and 687 million tonnes of carbon will be sequestered in the years 2000 and 2010 respectively (Table 4). There is however variation in the quantity of carbon expected to be sequestered by each species. Consequently cost of sequestering a unit of carbon varies with species (Table 4). On the average a unit of carbon will cost US$8.7 in year 2000 rising to US$34.59 in 2010.

In spite of the useful ecological roles projected for the aforementioned plantation projects, it is recognizable that the depressing financial resources of a third world country, like Nigeria, make such worthwhile and ambitious plan economically burdensome. In other words, international financial support is recommended in addition to private and community participation to make the GHG afforestation project successful. It is in this wise that the current discussion on "Debt for nature swap" is very relevant. Moreover, it is necessary that developed countries that emit most of these GHGs should be made to pay for them. It is also suggested that the GHG afforestation scheme be supported by appropriate policy and legislative structure directed towards ecological contribution rather than emphasising traditional commerical forest set-up alone.

CONCLUSION

Environmental deterioration is a worldwide problem. Environmentalists are particularly worried over the depletion of ozone layer and subsequent global warming through GHG emission and situation requires a comprehensive approach to forestry management. Most nations have established, or at least claim to be working towards institutions and laws to control and limit such destructive land-use practices of over-cultivation and deforestation Basic scientific management requires exact information about existing forest resources and their capability to sequester CO_2 .The available data suggests that the present strategy of forest management in Nigeria is inadequate for coping with the environmental threat of GHG emission in the country. A new strategy for forest management, in Nigeria, requires a sharp improvement of the present concepts of forest afforestation and management. The forest should not be seen as a collection of timber and pulp producing trees alone. Rather, it should be regarded as an ecosystem maintaining air - soil - water and vegetation balance. Afforestation is also to be seen as a re-establishment of needed ecological balance and interrelationship of air - soil - water - vegetation system lost by the destruction of the original tree cover.

Private participation and community involvement in forestry should be encouraged with financial support and incentives allocated on the basis of the regeneration of the actual tree cover.

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Table 1: Information on different species for afforestation: CO_2 emission reduction in Nigeria

S/N	PROPERTIES	NEEM	EUCALYPTUS	GMELINA	TEAK	NAUCLEA	ENTANDROPHRAGMA
1	Objectives	Fuelwood	Fuelwood & pole	Pulpwood	Sawnwood & pole	Sawnwood & pole	Veneer wood
2	Vegetation	Savanna	Savanna	Highforest	Woodland & H/forest	Highforest	Highforest
3	Rotation (years)	25	25	25	25	25	25
4	Harvesting periods (years)	5, 10, 15, 20, 25	6, 14, 20, 25	9, 16, 25	15, 25	15, 25	25
5	Biomass (tonne/ha)	24	91	157	170	202	202
6	Yield (m^3/ha)	90	90	200	216	200	200
7	MAI (m^3/ha/yr)	5	5	15	10	10	10
8	Wood density	0.7	0.9	0.7	0.8	0.9	0.9
9	Carbon content	0.45	0.50	0.70	0.70	0.70	0.65
10	Carbon increment	1.8	3.0	9.0	3.6	7.0	7.0
11	Cumulative carbon/ ha/rotation (tonne)	45	75	225	90	175	175

Table 2: Demand, Supply and Balance ('000m3) of wood and plantation areas ('000ha) required to meet shortfall of wood supply in different ecological zones of Nigeria

	2000				2010			
	Demand	Supply	Balance	Area required to meet shortfall	Demand	Supply	Balance	Area required to meet shortfall
FUELWOOD				-				
Forest	38684.0	63518.0	24834.0	-	40827.0	56575.0	15748.0	-
s/woodland	15509.0	6352.0	-9157.0	1831.4	16366.0	5140.0	-11226.0	2245.2
Savanna	29324.0	1569.0	-27755.0	5551.0	30945.0	1384.0	-29561.0	5912.2
Total	83517.0	71439.0	-12078.0	7382.4	88138.0	63099.0	-25039.0	8157.4
(b) POLES								
Forest	1011.0	720.0	-291.0	29.1	1254.0	687.0	-577.0	57.7
s/woodland	405.0	361.0	-44.0	8.8	507.0	294.0	-213.0	42.6
Savanna	786.0	191.0	-575.0	115.0	958.0	172.0	-786.0	157.2
Total	2182.0	1272.0	-910.0	152.9	2729.0	1153.0	1576	257.5
© SAWNLOG								
Forest	2758.0	2413.0	-345.0	34.5	4413.0	2001.0	-2412.0	241.2
s/woodland	1854.0	433.0	-1421.0	284.2	2966.0	344.0	-2622.0	524.4
Savanna	1767.0	150.0	-1617.0	323.4	2826.0	135.0	-2691.0	538.2
Total	6379.0	2996.0	-3386.0	607.6	10205.0	2480.0	-7725.0	1303.8
VENEER W OOD								
Forest	261.0	118.0	-163.0	16.3	466.0	100.0	-366.0	36.6
s/woodland	189.0	16.0	-173.0	34.6	313.0	13.0	-300.0	60.0
Savanna	180.0	2.0	-178.0	35.6	299.0	2.0	-297.0	59.4
Total	650.0	136.0	-514.0	86.5	1078.0	115.0	-963.0	156.0
(e) PULPWOOD								
Forest	191.0	568.0	377.0	-	354.0	568.0	214.0	-
s/woodland	95.0	50.0	-25.0	5.0	139.0	50.0	-89.0	17.8

	Demand	Supply	Balance	Area required to meet shortfall	Demand	Supply	Balance	Area required to meet shortfall
Savanna	144.0	109.0	-35.0	7.0	267.0	106.0	-161.0	32.2
Total	410.0	727.0	317.0	12.0	760.0	724.0	-36.0	50.0
TOTAL	93138.0	76570.0	-16568.0	8241.4	102910.0	67571.0	-35339.0	9924.3

Modified from Ojo (1994)

Table 3: Plantation areas ('000ha) for each wood use types for the different species in the years 2000 and 2010 for carbon dioxide emission in Nigeria

SPECIES/ WOOD.USE		NEEM	EUCALPTUS	GMELINA	TEAK	NAUCLEA	ENTANDROPHRAGMA
Fuelwood:	2000	4921	2461				
	2010	5438	2710				
Pole:	2000		51		51	51	
	2010		86		86	86	
Sawnwood:	2000				304	304	
	2010				652	651	
Veneerwood:	2000						87
	2010						156
Pulpwood:	2000			-			
	2010			29			
TOTAL							
	2000	4921	2512	-	355	355	87
	2010	5438	2805	29	738	737	156

Table 4: Forecast of plantation operational costs and carbon dioxide uptake (million tonnes) for Green house gas emission reduction in Nigeria.

SPECIES	2000 AREA (000HA)	EST. COST /HA (N)	TOTAL COST (MILL NAIRA	Cummulative carbon uptake (Mill. Tonnes)	2010 AREA (000HA)	EST. COST /HA (N)	TOTAL COST (MILL NAIRA	Cummulative carbon uptake (Mill. tonnes)
NEEM	4,921.00	39,000.00	191,919.00 ($2,399)*	221.4 ($10.8/C)	5,438.00	156,000.00	848,323.00 ($10,604)	244.7 (43.53/C)
EUCALYPTUS	2,512.00	38,700.00	89,679.00 ($1121)	188.4 ($5.85/C)	2,805.00	142,800.00	400,554.00 ($5004)	213.4 ($23.46/C)
GMELINA	-	-	-		29.00	359,880.00	11,481.00 ($144)	6.5 ($22.15/C)
TEAK	355.00	98,316.00	34,902.00 ($436)	31.95 ($13.65/C)	738.00	393,264.00	290,229.00 ($3,628)	66.42 ($54.62)
NAUCLEA	355.00	98,316.00	34,902.00 ($436)	62.13 ($7.02/C)	737.00	393,264.00	289,836.00 ($3,623)	128.98 ($20.13/C)
ENTANDRO-PHRAGMA	87.00	98,316.00	8,554.00 ($107)	15.20 ($7.04/C)	56.00	393,264.00	61,349.00 ($767)	27.30 ($28.1)
TOTAL	8,230.00	-	359,956.00 ($4,499)	519.08 ($8.7/C)	9.903.00	-	1,901,772.00 ($23,772)	687.3 ($34.59)

$1 = N80.00