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THE POTENTIAL OF NEEM TREE AS A BIOFUEL: A CASE STUDY FROM NIGER, WEST AFRICA

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ABSTRACT

The high price for international crude oil has generated a lot of interest in renewable energy, including oil extracted from tree-borne seeds. There are an estimated 300 tree species from whose seeds oil can be obtained. Neem is one of these species. This case study focuses on the potential of using neem as a biofuel in Niger, a poor, land-locked country in West Africa. Various value additions are highlighted, including the use of raw oil to produce electricity, pump groundwater, and run village flour mills. For the global community, neem plantations can help to mitigate climate change while also providing a source of carbon income for local communities planting and protecting such trees.

The paper traces the history of the spread of neem from South Asia to Africa where it was first introduced to serve as a shelter belt against desert storms. Neem has now become a social tree. Almost every village in Niger has a few of these trees under which important decisions are made by elders. However, the economic value of the tree has not been fully realized. The paper highlights the important results of a neem survey recently undertaken in the country to understand local uses and reports on the various village-level experiments being conducted to make use of the neem oil. The possibility of neem oil substituting for imported crude oil and the potential of carbon credits provide new dimensions in the current work on neem.

Keywords: Neem, biofuel, potential of neem tree, west africa,

INTRODUCTION

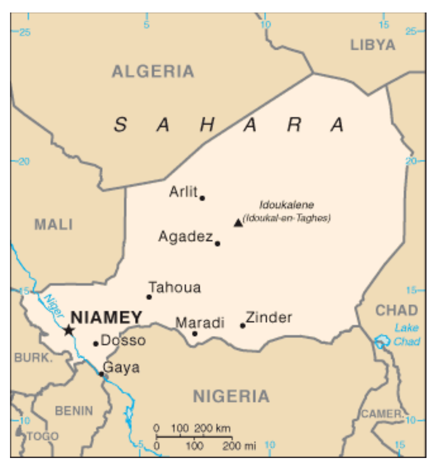
The high price for international crude oil has generated a lot of interest in renewable energy, including oil extracted from tree-borne seeds. There are an estimated 300 tree species in the tropical world from whose seeds oil can be obtained, but only four or five have been tested. This case study focuses on the various value additions from one tree species—neem or *Azadirachta indica*—in the West African country of Niger. Raw oil from neem has the potential to produce electricity, pump up groundwater, and run local equipment at the village level. For the global community, neem plantations can help to mitigate climate change, while also providing a source of carbon income for local communities involved in planting and protecting these trees. For the national government, there is also the possibility of creating rural employment, increasing income, improving the environment and displacing oil imports.

In this case study, we focus on the potential of using neem as a biofuel in Niger. The paper has four parts. The first part provides background of the country: the land, people, and the economy. The second summarizes the results of a neem survey, the first of its kind, during 2006. The third lists the various value additions undertaken in the country, such as oil extraction from seeds and the use of this oil in the village economy. The fourth part draws conclusions from the various activities undertaken and the possibilities for the future.

I. Country Background

Niger is a land-locked country in Sub-Saharan Africa (see map). Almost two-thirds of it is desert, though the flow of Niger river in the South provides some water for agriculture. With per capita income of US$ 210, Niger is regarded as one of the poorest countries on the planet. The World Bank says 63% of the population is poor. Some 13 million people live in a geographical space of 1.26 million square kilometers; this is projected to increase to 17 million people in 2015.[i] The growth of population is 3.4%, life expectancy at birth is 45 years, and infant mortality is 152 per 1,000 births.

The main ethnic groups belong to four tribes: Hausa (56%), Zarma (22%), Touareg (8%), Fulani (8%), and Kanouri (4%).[ii]



Agriculture contributes 40% to the economy and employs 90% of the population. The main occupations are farming and cattle herding. Pearl millet, sorghum, and cassava are Niger's principal rain-fed subsistence crops. Cowpeas and onion are grown for export.

After uranium, livestock is considered a major export, mainly to neighboring Nigeria. Cereal production in 2001 was 2,718 million tons. Meat production increased 34% between 1979-81 compared with 17% reduction in cereals during the same period. Nigeriens are considered big meat eaters.

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Niger has four agro-climatic zones:

- The ***Sahara*** zone covers 77% of the country and receives less than 100-150 mm per year.
- The ***Sahél- Sahara*** zone accounts for 12% of the land area and receives 150 mm to 350 mm of rain.
- The ***Sahel*** zone covers approximately 10% of the country and receives between 350 and 600 mm of rain.
- The ***Sudan*** zone in the south-west part of the country covers about 1% of the total surface and receives 600 to 800 mm of rain.

II. Neem Survey

Barely 1% of Niger's land mass is covered by forests. The high population growth puts additional pressure on existing forests. Consequently, some 679,000 hectares, or 35% of the forest area, has been lost between 1990 and 2005.[iii] Another reason for the loss is the spread of the Sahara desert at a rate of some 200,000 hectares annually. In an effort to slow the expansion of the desert, the government planted more than 60 million trees between 1985 and 1997 (*ibid*). The neem was one of the species planted.

Though neem has its origin in South Asia, it has become a multi-purpose tree in Niger. The tree is found in both cities and villages. It was introduced in the country in the 1940s first by migrants and then subsequently by the French colonial administration as part of environmental and agricultural services. Neem is resistant to arid conditions and grows even where rainfall averages 150 millimeters. The average rainfall in Niger varies between 200 millimeters in the desert north and 500 millimeters in the south.[iv]

Despite the wide diffusion of neem trees in Niger, there is very little data. Partly to fill this information gap, it was decided to conduct a survey to estimate the total number of trees existing in the country, the quantity of seeds that can be collected, the various uses made by the local population, and the amount of oil that could potentially be extracted from the seeds in the future. The survey was conducted in 2006.[v]

Because of limited financial resources and the fact that Niger is a vast country (about the size of Egypt) with a relatively sparse and widely dispersed population, the survey was limited to three areas along the Niger river: (i) the urban community of Niamey, the capital, around the Green Belt; (ii) the rural commune of Kirtachi in the department of Kollo in the south-east; and (iii) the commune of Sakouara in the department of Tillabery in the north-west. The survey was conducted in four villages in the two communes as well as in the urban community of Niamey.

In the villages, representative trees were enumerated and evaluated. In the Green Belt of Niamey, a large area planted to neem, sample plots measuring 50 meters by 50 meters were established to count the total stock (*ibid*). The results of the survey are discussed below.

Farmers' views

Farmers reported that, on average, a neem tree produced two to three bags of fruit per season if all the fruits were collected. The duration of fruit production is one month. Each bag weighed 100 kgs. However, the survey revealed that a farmer collected just two to three cups of seeds per day using tools like goblets, cups, buckets and bags. Earlier, farmers were not interested in collecting neem fruits or seeds, but with the initiation of a biofuel project by the NGO, EIP-Niger, the local population began to collect seeds and plant biofuel trees. *Pongamia pinnata, Jatropha curcas,* and *Moringa oleifera* are the other oil-bearing trees planted in addition to neem.

Traditional uses

Until the introduction of a biofuel project three years ago, farmers or their wives did not sell neem seeds. However, there were several traditional uses of the neem tree. The leaves were used as medicine, primarily to cure "the evils of belly" and hemorrhoid problems. In Sounga Dossado and Waly (two of the villages surveyed) leaves were burnt to repel mosquitoes. Leaves were also used as cattle feed. The stems of the tree were sawed into logs for use in construction. Small quantities of oil were extracted from neem seeds to protect cowpea and other crops from insects and fungi. The roots often served as a traditional drug. In its entirety, the neem tree is used as a windbreak, for shade, and as a tree of afforestation in the fight against desertification.

Survey results

Table 1 shows mixed results in the distribution of neem trees by age. Sounga-dossado and Banbangata villages had more adult trees (aged between 12 and 20 years) while Bonfeba and Wally had young trees (aged mostly between 1 and 6 years). Young trees indicate new plantations. In Bonfeba and Wally, the plantations were initiated by the NGO, EIP-Niger, as part of the biofuel project supported by USAID. Though not shown in the table, Banbangata and Bonfeba villages had considerable number of tree stumps, an indication of substantial ecological pressure as people look for fire wood.

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Table 1: Inventory of Neem trees based on age

Village	Young Neem trees		Adult Neem trees	
	Total number	Percentage	Total number	Percentage
Sounga-dossado	27	23	91	77
Banbangata	138	29	339	71
Bonfeba	458	62	275	38
Wally	199	82	43	18

Note: "Young trees" refers to the age group 5 to 9. Adult trees fall in the age group of 12 to 20 years.
Source: Tougiani 2006

The capital Niamey, a city of 775,000 people, is lined with neem trees. A large number of trees (41,800) were planted in the Green Belt area covering over 1,000 hectares between 1965 and 1988. More trees were planted by different public agencies to serve as shelter belt under various government schemes, particularly after the drought of 1984. Over 440,000 neem trees have been planted by the government in the capital city. The figure does not include trees planted by citizen, non-government groups, and seeds disseminated by birds.

Table 2: Distribution of Neem trees in Niamey

Site Categories	Area (ha)	Neem trees planted	Dead trees	Productive Adult trees	Stumps
1	1,045	418,000	241,918	130,103	45,980
2	43	17,200	9,955	5,354	1,892
3	14	5,656	3,273	1,760	622
Total	1,102	440,856	255,145	137,216	48,494

Note: Category 1: refers to the total number of neem trees planted in the Green Belt of Niamey between 1965 and 1988
Category 2: refers to trees planted by various government ministries on land under their control
Category 3: refers to trees planted under various government plantation schemes.
Source: Tougiani 2006

However, as Table 2 indicates, over half the trees planted are dead; only a third are still standing and productive. Most of the trees have been cut at some point. Sometimes, urban farmers prune

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trees just before the rainy season in order to facilitate better penetration of the sun for the crops they grow. Overall, there is considerable damage to the neem trees in the capital owing to pressure from the urban poor looking for fire wood and timber.

Table 3: Distribution of Neem trees and Quantity of Neem fruits and seeds per site

Site	Number of productive Neem trees/site	Mean fruit number/ Neem trees/site	Number of fruits per site	Weight of fruit per site (kg)	Weight of seed per site (kg)
Sounga-dossado	98	3,980	390,067	1,960	1,372
Babangata	375	4,191	1,571,638	7,500	5,250
Bonfeba	418	8,971	3,749,669	8,360	5,852
Wally	107	3,009	321,927	2,140	1,498
CUN	137,216	794	109,001,302	2,744,320	1,921,024

Note: The term "productive tree" refers to the reproductive efficiency of trees. CUN refers to the urban community of Niamey.
Source: Tougiani 2006

Table 3 quantifies the amount of fruits and seeds collected on average in the five surveyed sites—four villages plus the urban community of Niamey (CUN). The averages derived from these sites were extrapolated to estimate figures for the entire country. Even though the four villages are not truly representative of Niger, we decided that it would, nevertheless, be useful to make a countrywide estimate of neem trees, fruits, and seeds.

Estimates of neem production

The mean number of neem trees in the four villages surveyed was 250 trees per village. Each tree produced, on average, 20 kilograms of neem fruits, or 14 kilograms of seeds. Based on these averages—and the fact Niger had 10,676 villages in 1991, as reported by the Central Census Office—the following conclusions have been reached. Niger has 2,669,000 neem trees capable of producing 53,380,000 kilogram of fruits, or 37,366,000 kilograms of seeds. Based on existing technology in vogue in the country, the potential for neem oil is 12,143,950 liters, or 12,144 tons of oil.

The derived figure of 2.67 million trees tallies with the estimate of 2.2 million made by Maydell, 1990.[vi] Other estimates are on the higher side. Papaz (2003), who did a survey in the Zinder region, estimated that neem trees constituted between 52% and 59% of all trees planted in that region.[vii] From this survey, he estimated the total number of neem trees planted in Niger during

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the last 20 years at 69.65 million (Ministry of Environment and Water Resources, 2003).[viii] However, the survival rate of the planted trees has not been estimated in the survey.

The figure of 2 million plus neem trees is based on official data—ie, trees planted by government agencies over time. It does not take into account tree planting by individuals or non-governmental organizations. If the latter is taken into account, the figure would be several times higher—perhaps, in the range of 7 to 10 million trees.

III. Neem Value Additions

While the medicinal, pesticidal, agricultural, and environmental benefits of neem are well known, the biofuel possibilities have not been fully explored. The biofuel project in Niger funded by USAID for the past three years has experimented with neem oil in several villages. The focus of the project is not on neem, but a variety of tree species that can provide oil for use as a substitute for fossil fuel. Thus, a variety of oils from *Pongamia pinnata, Jatropha curcas* as well as *Azadirachta indica* are sought to be used to run local machinery, such as water pumps, flour mills, and other farm equipment. The goal is to source local oils to run local machinery and to sell surplus oil in the market. In many respects, the Niger project seeks to replicate the early experiments in Adilabad district, Andhra Pradesh, India where in addition to running farm equipment, raw oils are used to run transport vehicles and to produce electricity. The main source of these experiments in Adilabad district is oil from the pongamia tree.[ix]

Flour mills

Pearl millet is the staple food in most villages of Niger. Millet grows well even in the most arid conditions. Once harvested, millet is converted into flour by pounding it by hand. This task falls mainly on women who spend several hours a week. Often young girls help their mothers in this task. A motorized flour mill saves valuable time of women, but most villages in Niger have no electricity and diesel oil is very expensive and not easily accessible in rural areas. For this reason, the project decided to test the use of neem oil in running a motorized engine.

Various combinations of neem oil were tested with kerosene, diesel oil, and petrol (see Table 4). The most economical blend was found to be neem oil (70%), kerosene (20%), and petrol (10%); this combination cost about CFA 255 per liter compared with CFA 575 for a liter of diesel oil, which is the most widely used fuel.[x] However, Sounga-dossado and Manga Koura villages, where new flour mills are installed, use a blend of neem oil with diesel oil in a 1:4 ratio. Neem oil is in short supply, though seed collection has increased. Nevertheless, the price of neem oil is about half that of petrol or diesel, hence it can serve as a good substitute for fossil fuel.

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Table 4. Comparison of fuel mixtures—Neem Oil with Gas Oil and Kerosene

Fuel/ Parameters	Diesel 100%	Neem oil 50%, Diesel 50%	Neem oil 50%, Kerosene 50%	Neem oil 70%, Kerosene 20% Petrol 10%
Density		0.876	0.812	0.825
Engine start	Easy start even when cold	Easy start even when cold	Normal even when cold	Easy start even when cold
Overheating – smoke	Low overheating, dark smoke	Low overheating, greyish smoke	No smoke, no heating	Very little smoke
Motor running	Noisy	Normal, less noise	Normal	Normal
Motor-off	Normal	Normal	Normal	Normal
Engine sound	Knocking sound	Normal, no knocking sound	Good; no knocking sound	Better than petrol motor
State of injection/ piston	Some deposit of carbon on piston, pretty oily	Piston less oily, low deposit of carbon	No deposit of carbon on piston	No deposit of carbon on piston, Less oily than the last case.
Fuel efficiency	1 liter for 3 hours and 34 minutes	1 liter for 4 hours and 35 minutes	1 liter for 4 hours and 34 minutes	1 liter for 4 hours and 30 minutes
Price of mixture (CFA)	575	412	325	255

Note: CFA price of various oils per liter in Niamey: Kerosene (400), Petrol (661), Diesel (575), Neem oil (250) estimate. The results in the table are based on testing by Attaher Mahamane, diesel engineer, as part of the biofuel project.

Pumping water

The same blend of neem oil and petro-diesel is used to run water pumps. Two such pumps have been installed in the villages of Seno and Waly to draw water from the Niger river. In Waly, the pump is used mainly to water a mixed tree plantation comprising neem, jatropha, pongamia, and moringa trees. In Seno, the pump is used to provide water to a biodiversity garden—which comprises both biofuel trees as well as vegetables. People of Seno are growing onions, potatoes, cassava, and other cash crops for the first time using water pumped from the river. The biodiversity garden concept is catching on as farmers begin to grow some of these crops on their farms. They no longer have to depend on the rains.

Generating electricity

Biofuel-powered electricity is the next experiment planned. A feasibility study will soon be underway in the village of Seno. The experiment will draw on the experience from Adilabad district, India where a local grid was first established in the village of Chalpadi in 2001. A 7.5 kVa generator provided electricity to all households for about three to four hours per night. The generator consumed about 1.5 liters of pongamia oil per hour, or about 6 liters per night. The power system was run entirely by women of the village who required each participating

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household to contribute pongamia seeds as payment. The system in Seno is expected to be run on a blend of neem oil and petro diesel when it becomes operational.

Oilcake

In Niger, oil extraction from neem seeds so far has yielded 25% oil by weight—the proportion is higher in India—the balance is oilcake. The residue contains many chemical properties that are valuable for growth of plants. The nutritional properties of neem, pongamia, and other oilcakes are shown in Table 5. The table indicates that neem cake has good fertilizer properties—certainly as good as, or better than farm yard manure. This is significant for Niger because farmers consider the use of fertilizer on their crops to be expensive and risky. As a result, average fertilizer use in Niger is 8 kilograms per hectare compared with 90 kilograms in India. Microdosing—adding a pinch of fertilizer per seed—is one of the solutions recommended by ICRISAT to overcome crop nutritional deficiency in Sub-Saharan Africa.[xi]

Table 5. Nutritional Value of Neem Oilcake against Other Substitutes

Type of fertilizer or substitute	Nitrogen (N)	Phosphorus (P)	Potassium (K)
Neem oilcake	5.0	1.0	1.5
Pongamia oilcake	4.6	0.54	0.56
Farm yard manure	0.97	0.69	1.66
Vermicompost	0.51-1.61	0.19-1.02	0.15-0.73
Di-Ammonium Sulphate	18	20	0
Urea	46	0	0

Note: 1 bag of Di-Ammonia Phosphate (DAP) contains 9 kg of N and 23 kg of P2O5; the N:P:K values are in percentage

Source: D'Silva, Wani, and Nagnath 2004. [9]

Recently, neem cake was tested as fertilizer in growing tomatoes on two plots in Niger. The results from one of the plots are shown in Table 6; they show that 300 kilograms of neem cake per hectare (an optimum dosage for tomatoes) yields 15% increase in yields.

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Table 6. Impact of Neem Oilcake on Tomatoes, Niger Village, 2007

Plot size 1m x 1m	0 grams of cake	100 grams	200 g	300 g	400 g
No of tomato plants planted	9	9	9	9	9
No of tomato plants at maturity	9	8	9	7	3
Quantity of tomatoes harvested (kg)	10.3	11	10.5	15	9.1

Source: Experiment conducted for EIP-Niger by Antoine Lompo

Table 7. Impact of Pongamia Oilcake on Cotton, Powerguda Village, India 2004

Fertilizer treatment	Average cotton yield (g/sq m	Increase over farmers' practice (%)
Farmers' practice: 1 bag DAP	125	--
Inorganic fertilizer: 120 kg N/ha	174	39
Pongamia oilcake: 300 kg/ha	156	25
50:50 mix: Inorganic fertilizer (60 kg N/ha) + Pongamia cake (150 kg/ha)	179	43

Note: 1 bag of Di-Ammonia Phosphate (DAP) contains 9 kg of N and 23 kg of P2O5
Source: D'Silva, Wani, and Nagnath 2004.[xii]

In Adilabad district, India similar results were achieved for cotton when an equal quantity of pongamia oilcake was used (see Table 7). The yield of cotton increased 25% when compared with farmers' practices. Newer experiments in the district combine vermicompost and oilcake to serve as fertilizer for organic cotton for which there is increasing demand overseas. Farmers report decrease in production cost and increase in income as a result of going organic.

Carbon credits

The provisions of the Clean Development Mechanism (CDM) of the Kyoto Protocol provide an incentive to local communities to take up biofuel plantations. When the provisions for carbon sequestration and fuel switch are combined, the gains can be meaningful. However, the transaction costs involved in putting together a CDM project can be substantial—ranging from \$50,000 to \$250,000 or more depending on the size and activities of the project.[xiii] Even though the CDM Executive Board has developed simplified methodologies for small projects, the

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transaction costs are still prohibitively large for small communities unless these costs are subsidized by rich countries.

The voluntary emission reduction (VER) market in which some NGOs and small buyers look for community-driven projects offers better scope than the official certified emission reduction (CER) market operating under the guidelines of the United Nations Framework Convention for Climate Change. To the best of our knowledge, no CDM project has been developed in Niger either for the voluntary market or for the CDM Board. However, this is about to change as there are plans to use the provisions of fuel switch to market verified emission reduction from the biofuel plantations in the five villages supported by the biofuel project. The Adilabad model will be used for this purpose.

In Adilabad, India 44 have villages benefited from the sale of verified emission reduction to a variety of buyers, both Indian and international. The carbon income has served as seed money to local communities to continue reforestation and other sustainable development activities. Chalpadi, which pioneered electricity generation from pongamia oil, became the first village in India to sell carbon credits in March 2003.[xiv] The equivalent of 907 tons of carbon dioxide worth $4,164 was sold to a German NGO in verified emission reduction. In October 2003, Powerguda village sold 147 tons of carbon dioxide emission reduction to the World Bank.[xv] Individuals, citizen groups, and companies have purchased carbon to offset their emissions. We believe what has worked in India should also work in Niger.

Biodiesel

The most valuable end of the biofuel value chain is biodiesel production. Biodiesel is the name given to a variety of ester-based oxygenated fuels made from vegetable oils, fatty acids, used cooking oils, and other raw material. In Europe, biodiesel is produced mainly from rape seed and in the United States from maize and soybeans. In India, most of the raw material for biodiesel will come from *Pongamia pinnata* and *Jatropha curcas* grown mainly on degraded lands. India's first commercial-sized biodiesel plant with a capacity of 10,000 tons of oil has come up in Nalgonda district, Andhra Pradesh in which small farmers are important suppliers. We believe it should be possible for Niger to produce biodiesel on a small scale using the existing resource of neem trees. This may take another two years to put up a small plant to process biodiesel.

IV. Conclusions and Recommendations

While the medicinal and agricultural properties of the neem tree are well known and documented, the potential of neem oil as a biofuel has not been fully explored. The paper has provided evidence of this potential by reporting on the results of a neem survey as well as

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experiments undertaken in Niger. Neem oil has been used to pump water and run village flour mills. The possibility of using this oil to generate electricity in rural areas is being explored.

The neem survey of 2006 estimated that Niger has 2.67 million trees capable of producing 53.38 million kilogram of fruits, or 37.36 million kilograms of seeds. Based on existing technology, the potential for neem oil is 12.14 million liters, or 12,144 tons of oil. The survey was limited to only three agroclimatic zones, and a small number of villages, so the figure could be an underestimate. Figures in the range of 7-10 million neem trees are mentioned unofficially. What is clear, however, is that there is a vast pool of neem resource that has not been fully utilized. The vast size of the country, and wide dispersal of the population, means that collecting and transporting seeds will be a major challenge, but this challenge can be met once rural people become aware of the economic value of neem seeds.

The evidence presented in the paper shows that mixing neem oil with various proportions of diesel, petrol, and kerosene is possible to make the blend financially viable, environmentally beneficial, and for the smoother working of the engine. Field tests from using this blend oil to run flour mills and motor pumps have revealed that optimum results are obtained from blending 70% of neem oil with 20% kerosene and 10% petrol; this combination costs CFA 255 (US 54 cents) compared with CFA 575 (US$ 1.22) for a liter of diesel. However, from a practical standpoint, villagers prefer mixing 25% neem oil with 75% diesel. The lower proportion of neem oil is an indication of limited supply.

Apart from yielding biofuel, neem seeds also result in oilcake which can be an important source of fertilizer in a country where fertilizer use is one of the lowest in the world. This will help improve the productivity of millets and other crops in Niger. Crop productivity can be further enhanced by combining neem oilcake with vermicompost. Along the Niger river, compost is being produced from water hyacinths, a free-floating perennial aquatic plant that has become an invasive species.

Converting biofuel into biodiesel is an achievable goal in Niger, but this could take at least two years or more. Oil stocks will need to be built, a network of seed collection and oil extraction will need to be established, and a large tree planting program comprising a variety of oil-bearing trees undertaken. Niger has large tracts of land that can be used for tree planting and, some believe, sufficient ground water to water the trees. Biodiesel production will provide some financial relief to the country since it imports all of its oil requirements from neighboring Nigeria and other oil producers.

A biofuel plantation can have multiple benefits. For the global community, biofuel plantations can help to mitigate climate change, while also providing a source of carbon income for local

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communities involved in planting and protecting these trees. For the national government, a biofuel economy has the possibility of creating rural employment, increasing income, improving the environment and displacing oil imports.

There are possibilities for using the provisions of Kyoto Protocol's Clean Development Mechanism to market emission reductions from biofuel plantations in Niger. The experience from Adilabad district, India has shown that carbon income can serve as an incentive to local communities to plant and protect trees. However, it should be noted that carbon income constitutes barely 3% of total income from biofuel plantations. The main sources of income are oil (58%) and oilcake (38%). It does not make any sense to plant trees for the sole purpose of obtaining carbon credits (D'Silva 2005).

The paper has focused on the neem tree, in large part, because neem trees are found in many countries of Sub-Saharan Africa. The neem survey in Niger as well as experiments in the use of neem oil demonstrates that what has been done in Niger can easily be replicated in.

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