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COMPARATIVE STUDY OF THE UTILIZATION OF *SENEGALIA SENEGAL* AND *AZADIRACHTA INDICA* FOR RESOLUTION OF PHYSICAL AND SOCIOECONOMIC CRISES IN SUDANO-SAHEL NIGERIA: A REVIEW

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ABSTRACT
This paper compares the utilization of Senegalia senegal (Gum Arabic) and Azadirachta indica (Neem) in the resolution of physical and socioeconomic crises in Sudano-Sahel Nigeria. A critical analysis of the civics and utilization of both species revealed that Azadirachta indica was the best option particularly with the increasing threats of desertification, livelihood problems and farmer-grazer conflict in the region. However, its economic potentials remained under-exploited. On the contrary, Senegalia senegal also performed both the physical and social functions but to a less extent. Financial and economic studies had attested to its high economic viability. It was concluded that Azadirachta indica had greater positive impact on environment, livelihood and resolution of conflict compared to Senegalia senegal. Critical SWOT analysis based on the three universal questions of plantation forestry (Which tree species? Where and Why?), was strongly recommended for species to be involved in the resolution of all physical and socioeconomic challenges.

Key words: Senegalia senegal, Azadirachta indica, physical and socioeconomic crises

INTRODUCTION
The region Sudano-Sahel Nigeria covers the extreme northern part of the country (Figure 1) and is bedeviled by physical and socioeconomic crises. Physically, the region loses large expanse of both arable and marginal lands, infrastructural facilities, community settlements, rivers, lakes, oasis and streams attributable to the consequences of climate change and other agents of environmental degradation (UNCCD, 2014). Socioeconomically, it is the most poverty stricken region where living expenditure of an individual per day is less than 1US $ (UNDP 2018). This, coupled with extreme hunger makes the region highly turbulent and vulnerable to conflict and extremism (Roxo *et. al.*, 2004).Today, the region records the highest rate of rural-urban-drift with attendant chaotic growth of cities, unemployment, antisocial behavior and political instability positively correlated to the degrading quality of life of the people (NPC 2019). The situation is so dire that hundreds of people are killed annually besides destruction of thousands of crop and livestock products (Muhammad, 2016). In other words, the physical, social and economic development potentials of the region have not been sustainably harnessed. Consequently, environmental degradation, general insecurity, extreme hunger and poverty have taken their tolls in recent times (UNDP, 2005). Various intervention programs accomplished by a number of environmental stakeholders including NEADP, UNDP and FAO in collaboration with the State`s Ministry of Environment and the State`s Afforestation Project spread over a period of nearly two decades did not make significant impact. What to do? This paper stresses the need for identification and involvement of local tree species that can optimally generate physical and socioeconomic utility to counteract the multifaceted crises ravaging the region. What are the local species suitable for this task?

Selection of Desirable Species
Hundreds of local tree species flourish in Sudano-Sahel Nigeria. These species are not only adapted to the agro-ecological conditions of the region but also provide numerous and varied physical as well as socioeconomic services. However, the extent varies as does the species. Based on tree selection criteria (Wilkinson and Elevitch, 2012;

FAO &YSAP, 2014) and critical analysis of Strengths, Weaknesses, Opportunities and possible Threats (SWOT) as well as in compliance with the best silvicultural practices of plantation forestry, this work selects and compares *Senegalia senegal* (gum Arabic) and *Azadirachta indica* (neem) in the resolution of both physical and socioeconomic crises prevailing in Sudano-Sahel Nigeria. There are three principal reasons for that decision. Both species:

(i) Thrive well in all parts of the region hence they are highly adapted to its ecological conditions.

(ii) Have been used successfully in various afforestation and reforestation projects as well as in sand dune fixation and stabilization programmes.

(iii) Have products of high market value and can therefore serve as other sources of revenue.

Senegalia senegal and *Azadirachta indica* are not only frequently utilized in environmental management and livelihood programs of the region but also enjoy global popularity. For instance, gum Arabic is widely known as: the ***desert gold*** and a promising desert flora that can change the economic fortunes of any nation (Daily Trust, 2006). In contrast, neem is popularly known as ***a tree with solution to all global problems*** (World Neem Foundation, 2012). This attests to its declaration as the tree of the 21st century by the United Nations. Evidently, both species have the potentials for achieving both objectives but the extent may differ. This necessitates the need for critical assessment of each species from silvicultural, physical and socioeconomic perspectives. The resultant information generated could form the bases of comparisons and contrasts between them.

General Overview of *Senegalia senegal* and *Azadirachta indica*

Senegalia senegal is a leguminous multi-purpose African tree highly valued for its Gum Arabic produce. It is one of the most versatile leguminous trees with positive Agroforestry function

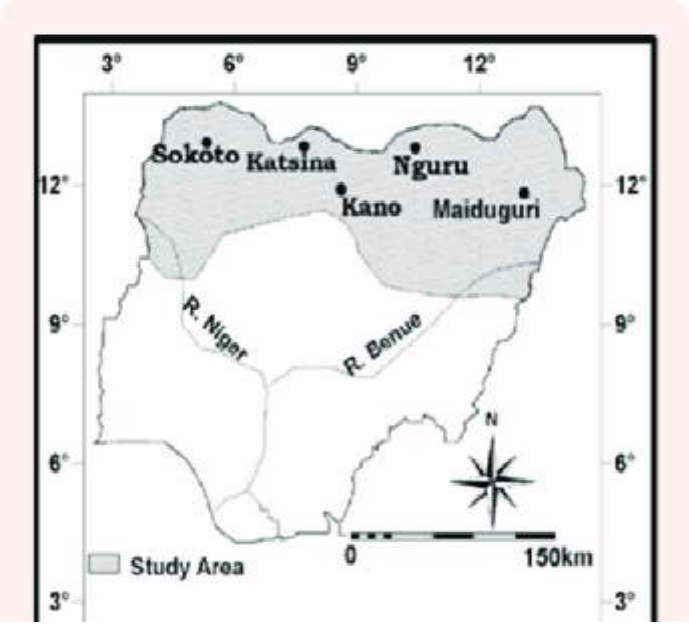

Figure 1 Map of Nigeria showing areas covered by the Sudano-Sahel region

Source: Daniel, I. E. et.al. (2018)

It is drought resistant as it can tolerate high temperatures, wind and sandstorm making it desirable for desertification control (Fact Net, 2002). In contrast, *Azadirachta indica is* also a versatile multipurpose tree for urban re-greening, Agroforestry, wood and fuel wood production and for a variety of other purposes including bio-pesticide production (Stoney, 2005). Moreover, its xyrophytic properties make it draught tolerant essential for desertification control.

From the above overview, it is evident that both species are:

a) drought tolerant and therefore suitable for use in programmes and projects of desertification control.

b) versatile multipurpose trees and thus have various uses and diversified income sources.

c) desirable for silvopastoralism and other agroforestry practices and can therefore be used to settle mobile grazers and avert the prevailing arable farmer-grazer conflict in the region.

Taxonomy

Difference exists in their respective taxonomies. *Senegalia Senegal* belongs to leguminous sub-family *Mimosoideae* (Fact, net, 2001) whereas *Azadirachta indica* has been botanically grouped in the *Meliaceae* or the mahogany family(UNEP, 2012).

Brief Botany of *Senegalia senegal* and *Azadirachta indica*

According to the United Nation Environmental Program (UNEP) (2003) *Senegaliia senegal* is a deciduous tree which grows to a height of between 2 – 15m with flat or rounded crown. It has poor and short bole. The tree has many branches and erected twigs spreading within the upright part. The bark is typically brownish yellow and smooth on younger trees changing gradually to dark grey, gnarled and cracked on older trees. The branches have thorns just below the nodes; either three thorns with the central one hooked downwards and literals curved upwards or a single thorn with literal absent. Leaves are small, grey-green alternate and bipinnate. Pinnae occur in (2-), 3 – 8(-12) pairs and leaflets in 7 – 25 pairs. The rachises sometimes have prickles. Flowers are white or cream colored and occur on 2 – 12cm long spikes. Pods are dehiscent, yellowish to brown, flat papery and oblong. Seeds are nearly round to flat olive brown and 8 – 12 mm in diameter. The tree flowers during the rainy season. Unlike *Azadirachta indica*, there are differences between the young and old trees of *Senegalia senegal* with respect to bark coloration.

In contrast, *Azadirachta indica* can be *evergreen* or *deciduous* depending on climate (Fact Net, 2005). Regardless of the climate, leafless periods are usually brief occurring only during periods of unbearingly extended droughts. At maturity, the height is twice (2x) that of *Acacia senegal* (15m – 30m). The tree branches extensively at 2 – 5m forming a broad, dense round or oval crown as oppose to sparse flat or rounded crown of *Senegalia senegal*. Neem has a stem diameter ranging from 30 – 90cm (2 - 3xs larger*).* Unlike *Senegalia senegal*, *Azadirachta indica* has well-developed lateral root system which extends up to 15m deep but with relatively shorter taproot. Bark coloration in *Azadirachta indica* is the same for both young and matured trees i.e. moderately thick, fissured and gray on the outer part but reddish brown on the inner. *Senegalia senegal* has short and sharp thorns with narrower leaves whereas *Azadirachta indica* is thorn less with broader leaves. Although both species have alternate leaf arrangement, the phyllotaxy is bipinnate in *Senegalia senegal* and imparipinnate in *Azadirachta indica*. Flowers are either white or cream colored in both species but are bisexual, sweet, scented, numerous and small in *Azadirachta indica*. The fruit of *Senegalia senegal* is oblong and rectangular with many seeds as oppose to those of *Azadirachta indica* which are smooth ellipsoidal drupe, 1.2 to 2.0cm long with usually one seed. Matured fruits of *Azadirachta indica* changes color from initial green to yellow as it ripen. This is not noticeable in *Senegalia senegal*. The color of matured gum Arabic nodules is pale yellow to reddish brown depending on the specie. It is crucial to note that *Azadirachta indica* are highly prolific fruit producers commencing at 3 – 5 years and becoming fully productive at 10 – 12 years (Fact Net, 2005).

Evidently, the botany of both species points to the fact that right selection was made with respect to attainment of the set objectives. However, the way, the manner and the extent they achieve these objectives may vary. For instance, while *Senegalia senegal* remains deciduous, *Azadirachta indica* can be evergreen or deciduous depending on climate. In case of Sudano-Sahel region, it is evergreen in both the northern and the southern parts despite considerable climatic variations between both areas. This guarantees not only continuous protection to the land surface from the negative impacts of wind, rain and solar radiation but also ameliorates the local weather. Based on this, *Azadirachta indica* may be preferred to *Senegalia*

senegal. However, this single botanical variable is inadequate for conclusive decision. Other botanical sub-variables with positive environmental and socioeconomic implications are worth considering. Important growth properties such as height and tree crown are also crucial. Available data have shown that *Azadirachta indicia's* height is about twice that of *Senegalia senegal's* at maturity; and although both had rounded or oval shaped crown, it was broader and denser in *Azadirachta indica* than in *Senegalia senegal*. It is logical that the greater the height and the denser the crown, the greater the microclimatic potential. Viewed from this angle, *Azadirachta indica* offered another greater protection from desertification. Adaptation is yet another factor of great importance and since both trees thrive well in the Sudano/Sahel agro ecology, they are highly adapted but the extent here also varies considerably. For instance, *Senegalia senegal* has thorns and smaller leaves which are effective adaptation against water loss. Thorns are lacking and leaves are broader in *Azadirachta indica* yet it is highly adapted to numerous and varied agro-ecological conditions (Parmar and Randhawa, 1993). Again, it is highly draught tolerant and once it gets established, it can survive 7 – 8 months of dry season as the situation in the Northern part of the region (SMOE, 2006). These two important properties: ―broader adaptation and draught tolerance must be supported by certain botanical features of the tree. What makes *Azadirachta indica* highly adapted to the Sudano-Sahel climate without thorns and smaller leaves compared to *Senegalia senegal*? The National Academy of Science (2010) attributed the above properties to the development of long penetrating lateral root system up to 15m deep, presence of thick scaly bark and development of swollen water reservoirs along the shoot system. In contrast, *Senegalia senegal* lacks these special adaptive features but its smaller leaves, thorned branches and dry season abscission make it resist dry season of between 8 and 11 months making the draught tolerance of *Senegalia senegal* higher than *Azadirachta indica* for obvious reasons.

Ecology

Senegalia senegal performs best at altitudes ranging from 100 to 1700m. In contrast, *Azadirachta indica* prefers ecology with an altitude from base level to 700m. Both altitudes are within ranges prevailing in Sudano-Sahel (YBSES, 2008). However, the latter performs better than the former due to its widespread adaptation(NRC, 1992). Both species can withstand very high temperature but the extent is greater in *Senegalia senegal* (45 ^{0}C) than *Azadirachta indica* (40 ^{0}C) (Orwa, et.al. 2009). The moisture requirements of both species marches the average rainfall values of the region with *Azadirachta indica* requiring as little as 150mm compared to *Senegalia senegal* with 300 – 400mm per annum. Again, they are both tolerant to dry wind and sandstorms. However, A*zadirachta indica* exerts greater breaking effects on wind due to its evergreen, denser and broader canopy compared to *Senegalia Senegal* (Muhammad, 2016). This is opposing the sparser and narrower canopy as well as the dry season abscission of *Senegalia senegal* that exposes the land to the direct impact of the wind. Both species adapt to different soil types but the extent is broader in case of *Azadirachta indica* than those of *Senegalia senegal*. The level of tolerance to water logging or seasonal inundate varies between the species; it is greater in *Senegalia senegal* than in *Azadirachta indica*. Both species perform well between pH values of 5 and 7. Matured trees of both species are light demanders with greater extent in *Azadirachta indica* (NRC, 1992).

Propagation and Regeneration Methods

Although both species can be propagated by seeds, raising the seedlings in the nursery is the best. Seedlings of *Azadirachta indica* can also be propagated vegetatively by air layering, cuttings, grafting and tissue culture (Parma and Randhawa, 1993). Vegetative propagation doesn't work well with *Senegalia senegal*. Direct seeding proved cost effective with both species, but poor survival rates has been observed with *Azadirachta indica* particularly in drier zones than with *Senegalia senegal*. *Azadirachta indica* is a prolific seed producer but seed supply is frequently a problem due to decreasing seed viability with consequent poor germination percentage arising from improper storage. The seeds of *Senegalia senegal* on the other hand have good viability with uniform and high germination percentage (Alkali, 2010).Ripped seeds of *Azadirachta indica* can be made more viable by removing the pulp and

washing them thoroughly with water. Furthermore, air drying the seeds for 3 – 7 days reduces the moisture content to less than 30% (NRC, 1992). These treatments are not necessary in seed viability maintenance in *Senegalia senegal*. All that is needed is protection from insect pest and light. Both species can be raised in containers ranging from polyethene bags to rigid plastic containers that are durable. Temporary shades at early stages are highly recommended,1 – 2 months for *Azadirachta indica* and 1 – 3 months or more for *Senegalia senegal*. Thinning is one of the major silvicultural practices that improve the quality of seedlings produced. Both species show positive response at 4 – 6 weeks in case of *Senegalia senegal* and 3 – 5 weeks for *Azadirachta indica*. Seed germination in *Azadirachta indica* is accelerated by removing the seed coat whereas in *Senegalia senegal g*ermination is promoted by soaking the seeds in concentrated Sulphuric acid for 20 – 30 minutes or in cold water for 48 hours (FOA & UNEP, 2003). Pruning of *Senegalia senegal* is accomplished when the seedlings start to grow out of the pots but in *Azadirachta indica* it is normally delayed to the time of planting.

Pest and Diseases

Azadirachta indica has very few serious pests or diseases due to its insecticidal and suppressive properties on insect pests and microorganisms respectively. The most serious insect pests are scale insects including the Neem scale (*Palvinaria maxima*) and the oriental yellow scale (*Aspidiotus orientalis)* both of which can cause considerable damage. On the contrary, *Senegalia senegal* has many pests and diseases that can cause serious economic damage. These include the spiders (*Cyclops spp*), larval stage of *Coleoptera* (bruchids), *Lepidoptera* and *Hymenoptera* are popular seed destroyers in many plantations. Locusts (*Acridium melanorhodan*) can defoliate vast areas overnight. *Senegalia senegal* is also attacked by fungi *Cladosporium herbarium,Fusarium spp, Ravenelia acaciea senegalae* and *R. acaciocola (*Southgate, 1983).

Management

Young *Azadirachta indica* needs protection from weed and fire although matured trees can easily recover from fire damage. Once the root system is well established, growth is rapid in the first five years; later it slows down gradually. *Azadirachta indica* responds well to coppicing and pollarding practices required for poles, posts and fuel wood production. Coppicing for fuel wood is managed on a 7 – 8 year cycle. Pollarding is accomplished to produce windbreaks and posts (Stoney, 2012). Nursery and plantation management of *Senegalia senegal* is basically the same with *Azadirachta indica* .It concentrates on controlling the effects of weeds, fire and grazing. Here, weeding is accomplished intensively during the early stages of growth. Fire terraces are normally provided round the plantation. Fire devastated plantations/nurseries do not recover hence preventive measures are the best. Grazing is detrimental but proper fencing along with regular supervision checks that. Coppicing and pollarding abilities are good but comparatively lower than in *Azadirachta indica.*

Uses

Both species have wide range of uses but the major ones that dominate literature can be grouped into three as follows:- (a) physical (b) social and; (c) economic uses. Both species perform the above functions, but the way and the manner these functions are accomplished differ greatly between them. Furthermore, it is important to know whether there is any risk associated with large-scale utilization of either of the species in realizing the above uses.

(a) Physical/environmental uses

This aspect analyzes and compares the modification power of both species on the target environment. It entails both preventive and curative measures against environmental degradation as well as strategies for making it more conducive for social, physical and economic activities. These uses include

(i) Desertification Control:

The Vanguard (2012) – one of the leading newspapers in Nigeria dated 03/05/2012 carried the following headline***:-***

"Neem trees can combat desertification and create jobs".

"the need for Paradigm shift in Combating Desertification in Northern Nigeria through neem plantation (Mohammed, 2011)."

In its bid to control desertification, the Federal Government has set aside over one hundred and

two million (N102, 000,000) for Green Village Development projects using neem in 11 frontline states under the Great Green Sahara Programme (Okoruwa, 2014).

In fact, in the Sudano-Sahel region, *Azadirachta indica* is widely used in desertification control and in sand dune fixation and stabilization programmes as well as in re-greening cities and rural settlements devastated by desertification.

Its microclimatic potentials is attested by its capacity to do the job of 10 air conditioners and can lower the temperature of its surroundings by 10^0C less than the outside ambient temperature (Neem Foundation, 2012).

Senegalia senegal is also used in desertification control programs but the extent is relatively lower compared to *Azadirachta indica.* Principally, it is grown for economic reasons. For instance, reports like the following confirm:

Jigawa State government set to tackle poverty and unemployment with gum Arabic development (Newswatch, 2002).

Poverty Reduction Programme: Federal Government budgets N72, 445,945 for the establishment of Gum Arabic plantation (Leadership, 2014).

Gum Arabic tree is valued in the world for its high quality gum, which is a foreign exchange earner (Mokwunye and Aghughu, 2010)".

Processing Gum Arabic for huge profit making in Nigeria (FORAMINIFERA, 2013).

In general, both trees have been and still used in desertification control programmes but in Sudano-Sahel Nigeria, the performance of the above function is primary in case of *Azadirachta indica* and secondary in *Senegalia senegal*. However, researches nowadays point to the fact that economic potentialities of *Azadirachta indica* are on the increase and are receiving global attention.

(ii) Erosion control:

The evergreen attribute of *Azadirachta indica* protects the soil against the negative impacts of wind and water erosion throughout the year. *Senegalia senegal* on the other hand protects the soil particularly during the rainy season but in the dry season, abscission in response to seasonal water shortages sets in and this exposes the entire land surface to the direct impacts of wind and water.

(iii) Shade/shelter

Neem plays an important role in both urban and rural landscapes. Its well formed crown, its evergreen nature and its short deciduous period guarantee this (Stoney, 2012). These attributes make it a popular choice for both avenue functions as well as for shade plantings around buildings and along major roads. It is also used on farms as a pasture tree to shade livestock and in boundary rows. In comparison, *Senegalia senegal* does not make a good shade or shelter due to its poor crown and seasonal abscission (Muhammad, 2016).

(iv) Agroforestry

Agroforestry projects involving both species ensure positive interaction between the trees and arable crops as well as economic stability of farm enterprise (Carter, 2005). This is achieved by using neem trees on the farm as windbreaks and shelterbelts to protect crops and animals from wind damage and soils from erosion. *Senegalia senegal* in contrast is an excellent Agroforestry tree species that serves both objectives of Agroforestry i.e. besides positive interaction, it also stabilizes the economy of the farm enterprises. This is supported by its leguminous nature, which allows it to fix large quantities of nitrogen that are beneficial to the arable crops leading to higher output. Furthermore, the sale of the gum Arabic nodules generates cash income to the forest farm. In other words; Agroforestry systems involving *Senegalia senegal* serve dual economic functions of increased Gum Arabic produce as well as increased crop output (Zira 2014).

(v) Soil improvement:

Farmers in India use neem cake as an organic soil amendment. Researches have shown that it significantly enhances the efficiency of nitrogenous fertilizers by reducing nitrification rate and inhibiting soil pests and diseases including nematodes, other insects and fungi respectively (Orwa *et.al*, 2009). Furthermore, the leaves and tender twigs of *Azadirachta indica* are suitable mulches and green manures (NRC, 1992). *Senegalia senegal* on the other hand improves the lots of poor soils particularly those with poor textural and structural stabilities

through nitrogen fixation already highlighted above. Furthermore, the dry season abscission adds organic matter to the soil thus enhancing its physical, chemical and biological conditions (Zira 2014). Therefore, it is also an excellent soil improver. Table 1 gives point-by-point comparisons of the uses of both species under investigation.

Economic uses

(i) Wood industry

Commercial production of *Azadirachta indica* could open up opportunities for establishment of wood processing industries in the region. This is because the wood is hard, durable and resistant to insects and fungi. The wood also shrinks very slightly on drying with excellent seasoning making it easy to work. Despite the fact that the wood does not polish well, saw timber can be used in light construction to make beams, doors and window frames, boxes, crates, carts, axles, yokes, cabinets, panels, boats, oars, cigar boxes, carvings, toys, drums and agricultural implements. Its insect repelling property allows it to be used in the construction of furniture especially wardrobes, bookcases and closets (Fact Net, 1997). Unlike *Azadirachta indica*, *Senegalia senegal* has not been used in the production of wood products in commercial quantities. Principal Wood products are limited to fuel wood, poles and posts which are used locally as secondary products (Brenan, 2003).

(ii) Pharmaceutical industry

Azadirachta indica is very popular among pharmaceutical industries used in the production of anti-malarial drugs due its high quinine content. It is the major active ingredient used in the formulation of effective antibiotics that suppress the activities of various fungi and pathogenic bacteria including Salmonella typhosa and staphylococcus aureus as well as in the production of drugs used in the treatment of leprosy, tapeworms, ulcers, eye diseases, hepatitis, ringworms and ant periodic rheumatism (Hocking, 1993). In contrast, *Senegalia senegal* supports pharmaceutical industries indirectly by serving as stabilizers for emulsions, binder and coating for tablets and directly as an ingredient used in the preparation of cough drops syrups (Anderson, 1989).

(iii) Soap industry

Azadirachta indica oil has for long been produced in Asia on an industrial scale to produce soaps for bathing and washing as well as other cleaning agents for both domestic and industrial uses (Neem Foundation, 2012). The use of *Senegalia senegal* in local and commercial soap production has not yet been reported.

(iv) Cosmetic industry

Azadirachta indica oil is used as a raw material for production of highly valued cosmetic materials that smooth the body and protects it against infection (Orwa *et.al.* 2009). Generally Neem oil provides raw materials for pharmaceutical, soap and cosmetic industries. Neem oil has high global value. It is extracted from the seed and constitutes 50% of the weight of the kernel. In 1990, it was valued at USD 700 per tonne (Orwa *et.al*. 2009). *Senegalia senegal* is also used in cosmetic industries to produce a variety of cosmetic products. This is possible by its adhesive property suitable for manufacture of facial masks and powders as well as in the production of skin lotions favored by its smooth feel (Cossalter, 1991).

(v) Printing industry

Azadirachta indica makes very little if any contribution to the printing industry. Literature does not record significant usage of neem in printing business even at the local level. In contrast, *Senegalia senegal* is used industrially as an adhesive and a protective colloids that safeguards ink materials, sensitizes lithographic plates and provides qualitative coatings for special papers (Cossalter, 1991). In fact, the literature is full of evidences that prove that *Senegalia senegal* can be grown at commercial scale to support printing industry in its entire ramifications.

(vi) Agrochemical industry

Azadirachta indica could be grown on large scale to provide raw materials for commercial production of pesticides. For instance, Azadirachtin is a principal active compound, which is extracted from seeds, leaves and other tissues of the neem tree. It is very effective in repelling insect pests by inhibiting feeding and disrupting their growth, metamorphosis and reproduction (Stoney, 2012). Neem-based formulations do not only kill insects directly but

also alter their behavior insignificantly to reduce pest damage as well as their reproductive potentials. Overall, test of neem extracts have shown positive results on about 300 species of insect pests mostly in the ***Orthoptera*** (grasshoppers, katydids, etc); ***Homoptera*** (aphids, leaf hoppers, etc); ***Dictyoptera*** (cockroaches and mantids); ***Lepidoptera*** (moths and butterflies); ***Heteroptera*** (true bugs); ***Diptera*** (flies); ***Coleoptera*** (beetles and weevils); ***Hymenoptera*** (bees, wasps and ants); ***Isoptera*** (termites); ***Thysanoptera*** (thrips), and ***Siphonaptera*** (flea) orders (NRC, 1992;Randhawa and Parma, 1993). More recent researches have identified other active compounds in neem tissues besides Azadirachtin, This explains the reason for the development and approval of several neem-based biological pest control (BPC) products for commercial distribution in some countries including India and the USA. Generally, neem-based formulations provide inexpensive integrated pest management (IPM) resource for farmers, raw materials for small rural enterprises or the development of Neem-based industries. There is very little or no evidence(s) of agrochemical production from extracts of gum Arabic tree.

(vii) Food industry

The use of *Azadirachta indica* in food industries at commercial or local scale has not yet been reported. *Senegalia senegal* on the other hand is used in food industries in much the same way it is used in pharmaceutical industries. For instance, it is used as a flavor fixative and emulsifier to prevent crystallization of sugars in confections. It is also used as a stabilizer in frozen dairy and bakery products for its viscosity and adhesive properties (Cossalter, 1991).

(viii) Ceramic industry:

There is no documented literature supporting the use of *Azadirachta indica* in ceramic pottery as oppose to the Gum Arabic utilization in the production of ceramic materials (Cossalter, 1991). It is unclear whether this usage is at local or commercial scale.

(ix) Medical industry

Azadirachta indica promotes the medical industry by being toxic to cultures of 14 common fungi (NAS, 1992). It also has suppressive effects on several species of pathogenic bacteria. Various parts of *Azadirachta indica* have anthelmintic, antiperiodic, antiseptic, diuretic and purgative actions. Neem oil is a powerful spermicide and can therefore be used cheaply in birth control. A neem oil-based product—Sensalis being marketed in India as an intravaginal contraceptive (NAS, 1992). Extracts of *Senegalia senegal* with toxic and suppressive effects on harmful micro-organisms have not yet been reported.

Table 1.0 Compares and Contrasts the Physical, Social and Economic Uses of Both Species.

S/no	Variable of comparison	Senegalia senegal	Azadirachta indica
	Physical/environmental uses		
1	Desertification control	High	Higher
2	Erosion control	High	Higher
3	Draught control	High	Higher
4	Agroforestry function	High	Higher
5	Soil improvement	Higher	High
	Social uses		
1	Avenue functions	Low	Very high
2	Agroforestry application to avert conflict	High	Higher
3	Re-greening programs	Low	Very high
4	Landscaping/beautification	Low	Very high
	Economic uses		
1	Wood for furniture and light construction	Very poor	Excellent
2	Raw material for pharmaceutical industries	Good; but indirectly used as stabilizers, binders and coatings for tablets	Excellent
3	Raw material for soap	Very Poor	Excellent
4	Raw material for cosmetics	Very Good	Excellent
5	Utilization in Printing industry	Excellent	Very Poor
6	Raw material for Agrochemicals	Excellent	Good
7	Utilization in food industry	Excellent	Very Poor
8	Utilization in Ceramic industry	Excellent	Very Poor

Source: Compilation from FAO & UNEP (2003), Fact Net (2005) and Orwa et.al (2009)

Risk Assessment

A review of the global invasive species database shows that large scale plantation of both trees does not pose serious ecological threat to the region. Furthermore, both species are not among 100 of the world worst invaders published by the above-named database (PIER, 2012). In other words, there has not been negative ecological report against them globally. However, at the local levels where these species were used to serve various purposes, both have been reported as weeds. According to Acacia factsheets (2011), *Senegalia senegal* can spread rapidly into fallow areas and become a weed. Similarly, a rhetoric question has recently been raised on *Azadirachta indica* as to whether it is a "Wonder Tree" or “Noxious Weed?”. These queries were prompted by a recent classical research work on the impact of neem trees on vegetation and wildlife in Northern Australia (neemweed, 2012). If a weed is a plant that invades and outcompetes native and cultivated

plants (PIESR, 2002), then in Sudano-Sahel region both species have nothing to invade and compete particularly in the northern part of the region where farmlands, villages and major roads have been overtaken by desertification. Based on this therefore, both species have very little ecological risk arising from large-scale utilization.

Physical assessment

Researchers have shown that *Azadirachta indica* had greater microclimatic and edaphic impacts in the region compared to *Senegalia senegal*. For instance, Zira (2014) and Muhammad (2016) reported higher rainfall and relative humidity as well as lower temperature and wind speed values in areas sheltered by *Azadirachta indica* compared to the protected areas of *Senegalia senegal as summarized in the table below*

Table 1.1 compares the impact of plantations of *Azadirachta indica* and *Senegalia Senegal* on four weather variables at Afunori, Nangere and Damaturu plantation areas of Yobe State, Nigeria

S/n	Weather Variable	Growth Stages	Mean value *A. indica*	Mean value *S. senegal*	Difference b/w Mean values	%
1	Rainfall	1999 - 2003	48.65	48.57	0.08	0.082
	(inches)	2004 – 2008	57.96	51.94	06.02**	05.48
		2009 – 2013	65.75	58.64	07.11**	05.72
2	RH (%)	1999 - 2003	39.46	38.93	0.53	0.68
		2004 - 2008	52.38	47.16	05.22**	05.24
		2009 – 2013	58.94	50.71	08.23**	07.51
3	Temperature	1999 - 2003	27.96	28.14	- 0.18	0.32
	(^{0}c)	2004 - 2008	23.49	28.48	- 04.99**	09.60
		2009 – 2013	22.96	27.44	- 04.48**	08.89
4	Wind Speed	1999 - 2003	15, 005.42	15, 236.37	- 230.95**	0.76
	(Knots)	2004 - 2008	10, 948.68	12, 898.96	1, 950.28**	08.18
		2009 – 2013	09, 259.20	11, 276.38	2, 017.18**	09.82

Source: Muhammad (2016), Key: RH = Relative humidity, *A. indica* = *Azadirachta indica* and *S. senegal* = *Senegalia Senegal* ** = Significant at $P \leq 5\%$

Similarly, results indicated greater positive impact on both physical and chemical soil parameters under the shelters of *Azadirachta indica* compared to the areas protected by *Senegalia senegal.*

Table 1.2 Succinctly Compares the Impact of Both Species on Physical Soil Properties at Afunori, Nangere and Damaturu Plantation Areas

S/n	Variable of comparison	Plantation Area	Control	*Azadirachta Indica*	*Senegalia senegal*	Difference b/w MV	%
1	Texture	APA	Sandy	Sandy loam	Sandy		
		NPA	Sandy clay	Sandy loam	Sandy clay		
		DPA	Sandy clay	Sandy clay loam	Sandy clay		
2	Bulk density						
		APA		1.20	1.59	- 0.39	-13.98
		NPA		1.43	1.98	- 0.55	-16.13
		DPA		1.36	1.49	- 0.13	- 4.56
	Mean			**1.33**	**1.69**	**- 0.36**	**- 11.92**
3	Porosity	APA		42.25	39.99	2.26	2.75
		NPA		46.16	41.83	4.33	4.92
		DPA		48.55	43.90	4.65	5.03
	Mean			**45.65**	**41.91**	**3.74**	**4.27**

Source: Muhammad (2016)

Key: APA = Afunori Plantation Area, NPA = Nangere Plantation Area, DPA = Damaturu Plantation Area, b/w = between MV = Mean Values

There was textural transformation, lesser BD values and higher percentage porosity in samples collected from the protected areas of Azadirachta *indica*. The exact opposite was the case with samples retrieved from the areas sheltered by *Senegalia senegal*.

Table 1.3 Summarizes and Compares Chemical Soil Properties Retrieved from Samples Collected from the Three Plantation Areas Under the Shelters of Both Species

S/n	Variable of comparison	Mean Value Control	Azadirachta Indica	Senegalia senegal	Difference b/w MV	%
1	Potential Hydrogen ions (pH)	05.40	7.27	7.40	- 0.13	- 0.89
2	Electrical Conductivity (EC) (ds/m)	29 $\pm$ 22	0.04	0.07	- 0.03	27.27
3	Organic Matter Content (OC) (%)	CDNA	0.82	0.52	0.30	22.39

4	Total Nitrogen (TN) (%)	CDNA	0.42	0.05	0.37	78.72
5	Available Phosphorous (AV-P) (%)	CDNA	9.39	8.66	0.73	4.04
6	Magnesium ions (Mg^{2+}) (cmol/kg)	0.28 $\pm$ 0.0	3.75	2.67	1.08	16.82
7	Calcium ions (Ca^{2+}) (cmol/kg)	BDL	3.67	3.20	0.47	6.84
8	Sodium ions (Na^{+}) (cmol/kg)	0.48 $\pm$ 0.1	0.10	0.17	- 0.07	25.93
9	Potassium ions (cmol/kg)	2.69 $\pm$ 0.1	0.83	0.57	0.26	11.57
10	Total Exchangeable Bases (TEB) (cmol/kg)	CDNA	7.33	6.61	0.72	5.16
11	Total Exchangeable Acidity (TEA) (%)	CDNA	2.57	1.73	0.84	19.53
12	Effective Cation Exchange Capacity (ECEC) (%)	CDNA	9.07	8.34	0.73	04.19
13	Base Saturation (BS) (%)	CDNA	82.79	79.03	3.76	02.32

Source Muhammad, (2016)
Key: CDNA = Control Data Not Available; BDL = Below Detection Limit b/w MV = between mean values

Elemental abundance, good p^H values, higher CEC and other favorable chemical attributes of fertile and productive soils were recorded more from samples sheltered by *Azadirachta indica* than *Senegalia senegal*. This could be the reason for the higher GM values realized from farmlands protected by *Azadirachta indica* compared to *Senegalia senegal* at the same distances and stages of growth as shown in table 1.4 below

Table 1.4 Compares Gross Margin/Ha/Year Realized by Millet Farmers in the Protected Areas of Both Species at Afunori, Nangere and Damaturu Plantation Areas

S/n	**Stage of Growth**	**Distance (m)**	**Mean GM *A. Indica***	**Mean GM *A. Senegal***	**Differences between mean values of Gross Margin**
1	1999-2003	≤100	55,569.89	55,086.89	483.00
	2003-2008	≤100	89,490.87	76,759.79	12,731.08
	2009-2013	≤100	169,217.06	145,507.98	23,709.08
2	1999-2003	≤150	52,331.17	50,202.75	2,128.42
	2003-2008	≤150	81,536.61	70,803.61	10,733.00
	2009-2013	≤150	161,133.54	135,994.05	25,139.49
3	1999-2003	≤ 200	51,114.98	48,076.18	3,038.80
	2003-2008	≤ 200	78,750.68	65,462.85	13,287.83

2009-2013	≤ 200	157,288.41	130,630.43	26,657.98

Source Muhammad, (2016)

Social Assessment

Azadirachta indica provides more social services compared to *Senegalia senegal*. These services range from being an avenue tree species to beautification and resolution of conflict when grown in combination with palatable pasture and forage species for livestock consumption (Zira 2014)

Economic and Financial Assessments

Studies (Muhammad, 2016) conducted in three plantation areas of Afunori, Damaturu and Nangere with each involving two plantations of both species established in 1999 have shown that *Azadirachta indica* had higher significant economic impact when used in desertification control projects compared to *Senegalia senegal (Table 1.4).* However, the establishment cost per hectare for the latter was significantly higher than that of the former, but difference between management cost per hectare for both species was invariably the same as summarized in tables 1.5 and 1.6.

Table 1.5 Compares Establishment Cost /Ha for Plantations of Both Species at Afunori, Nangere and Damaturu Plantation Areas

S/n	Expenditure	Year incurred	Mean Cost/ha ₦ S. senegal	Mean Cost/ha ₦ A. indica	Difference between Mean values (₦)/ha	%
1	Land	1999	12, 666.67	12, 666.67	0.00	0.00
2	Fencing	1999	199, 309.54	0.00	199, 309.54	100.00
3	Land preparation	1999	27, 257.92	23, 316.67	3, 941.25	7.79
4	Seedlings (cost & transport)	1999	5, 833.34	5, 000.00	833.34	7.69
5	Borehole (cost & maintenance)	1999	60, 533.33	59, 166.67	1, 366.67	1.14
6	Inputs (tools equipment & chemicals)	1999	9, 081.50	6, 553.34	2, 528.16	16.17
7	Micro Catchment Construction	1999	1, 833.33	1, 483.33	350.00	10.55
8	Fire terraces	1999	5, 000.00	4, 500.00	500.00	5.26
9	Security patrol	1999	16, 000.00	15, 000.00	1, 000.00	3.23
10	Total	-	**337, 515.63**	**127, 686.68**	**209, 828.95****	**45.10**

Source: Muhammad (2016)
** = significant at P ≤ 5%

Table 1.6 Compares Management Cost/Ha for the Plantations of Both Species at APA, NPA and DPA

S/n	Expenditure	Year incurred	Mean Cost/ha ₦ S. senegal	Mean Cost/ha ₦ A. indica	Difference between Mean values (₦)/ha	%
1	Replacement of dead stands	2000	1, 916.67	1, 500.00	416.67	12.19
2	Micro-catchment construction	2000	3, 833.33	3, 000.00	833.33	12.19
3	Fire terracing	2000	16, 500.00	16, 000.00	500.00	1.54
4	Security patrol	2000	28, 000.00	27, 000.00	1, 000.00	1.82
5	Pruning	2003	2, 833.33	2, 500.00	333.33	6.25
6	Seed harvesting and parking	2006	4, 500.00	4, 166.67	333.33	3.85
7	Trimming operations	2007	0.00	2, 000.00	- 2, 000.00	100.00
8	Total	-	**57, 583.33**	**56, 166.67**	**1, 416.66**	**1.25**

Source: Muhammad (2016)

Marketing of gum Arabic noodles generated higher net profit per ton per marketer compared to the corresponding value of neem seeds marketed within the same period (table 1.7).

Table 1.7: GM and Profitability Analysis for Gum Arabic and Neem Seed Marketing at APA, NPA and DPA

Variables (Items/Activities)	**Value (₦)/tone**	**Value (₦)/tone**	**Difference**	
	Gum Arabic	Neem Seeds	Value (₦)/tone	%
(A) **Depreciated Fixed Cost**				

i.	**Scales**	3, 350.41	2, 666.82	683.59	11.36
ii.	**Head pans**	1, 248.17	1, 157.31	90.86	3.78
iii.	**Measures/Modus**	372.07	310.62	61.45	9.00
Total Fixed Cost		4, 970.65	4, 134.75	835.90	9.1
(B)	**Variable Cost**				
i.	**Labor**	5, 343.88	4, 874.27	469.61	4.59
ii.	**Operating Cost**	14, 631.31	6, 432.99	8, 198.32	38.92
iii.	**Purchasing Cost**	184, 566.79	41, 694.27	142, 872.52	63.14
Total Variable Cost		204, 541.98	53, 001.53	151, 540.45	58.84
(C)	**Total Cost**	209, 512.63	57, 136.28	152, 376.35	57.14
(D)	**Total Revenue (TR)**	269, 590.09	81, 407.30	188, 182.79	53.61
(E)	**Gross Margin (D – B)**	65, 048.12	28, 406.18	36, 641.94	39.21
	GM/tone/Marketer	2, 601.92	1, 136.25	1, 465.67	39.21
(F)	**Net Profit (D – C)**	60, 077.47	23, 728.01	36, 349.46	43.37
	NP/tone/Marketer	2, 403.09	949.12	1, 453.97	43.37
(G)	**Total Number of respondents**	25	25	-	-
(H)	**Total Quantity Marketed**	685.41 tones	673.13 tones	-	-

Source: Muhammad (2016)

It was further established that gum Arabic plantations were economically more viable in all the three plantation areas with higher BC-R and with positive NPV and LEV values (Table 1.8)

Table 1.8 Compares the Economic Viabilities of Plantation Projects of Both Species at Apa, Npa and Dpa

S/n	**Economic Tool**	**Plantation Area**	**Value under *S. senegal***	**Value under A. *indica***
1	BC-R (24%)	APA	1.56	0.55
2	BC-R (24%)	NPA	1.40	0.61
3	BC-R (24%)	DPA	1.10	0.56
4	NPV (24%)	APA	N163, 036.60	-N67, 060.30
5	NPV (24%)	NPA	N106, 835.09	-N61, 572.47
6	NPV (24%)	DPA	N57, 101.57	-N79, 559.29
7	LEV (24%)	APA	N152, 370.65	-N62, 673.18

8	LEV (24%)	NPA	N99, 845.88	-N57, 544.36
9	LEV (24%)	DPA	N53, 365.95	-N74, 354.48

Muhammad, (2016).

DISCUSSIONS

The most pressing physical challenges bedeviling the region are drought and desertification. Although they are two different phenomena, they have common control measures. What makes *Azadirachta indica* more desirable than *Senegalia senegal* in terms of physical functions? From their botanical records, it is apparent that *Azadirachta indica* has a broader and a denser canopy than *Senegalia senegal* at maturity. The broader and denser the canopy, the greater the microclimatic power of the species (FAO & UNEP, 2003; Fish wick & Weber, 2012 and Zira, 2014). Thus, draught and desertification crises in Sudano-Sahel region can be more counteracted with *Azadirachta indica* than *Senegalia senegal* for obvious reasons. Furthermore, these botanical attributes protect the soil from the direct impact of extreme weather variables with resultant modification of both physical and biochemical soil conditions. The overall effect of all these is improved environmental management that can support higher crop and livestock production. With these, the hunger and poverty crises in the region can be more effectively resolved with *Azadirachta indica* than *Senegalia senegal.*

The arable farmer-grazer conflict is the major social crises prevailing in the Sudano-Sahel region. The migrating grazers encroach on farmlands and cause wanton destruction of farm produce. This causes conflict between both farming groups. Which of the species has the potentials to avert the raging conflict? Both the arable crop farmers and the herders need favorable environment to operate and since *Azadirachta indica* has greater microclimatic and edaphic potentials, it will be expedient to involve it in multiple land use programs particularly silvopastoralism or ruga settlement program. This can effectively settle the mobile grazers and at the same time promote sedentary agriculture (Zira, 2014). Thus, the turbulence and vulnerability of the region to conflict and extremism can be decelerated with the more usage of *Azadirachta indica* than *Senegalia senegal.*

Hunger and poverty constitute the major economic challenges in the region. *Senegalia senegal* has greater potentials to reduce extreme poverty to a manageable proportion. The high global market value it attracts can guarantee this. Again, its microclimatic and edaphic potentials can stimulate increased food production. However, its choice is negated by its higher palatability to small ruminants as well as its higher establishment cost occasioned by its unavoidable need for fencing (Muhammad, 2016). In addition, its microclimatic and edaphic potentials are significantly lower than those of *Azadirachta indica*. Therefore, its support to agricultural production is comparatively much lower.

CONCLUSION

Azadirachta indica and *Senegalia senegal* are widely used in programmes and projects of environmental management not only in the Sudano-Sahelian parts of the country but also in Sub-Sahara Africa. This is a clear proof of their wide range of adaptations to extreme climatic conditions. Although both species can be used in the mitigation of the prevailing physical and socioeconomic crises in the region, the extent is greater with *Azadirachta indica* than *Senegalia senegal*. This explains it's wide spread usage in the reclamation of degraded environment and in multiple land use programs. This work unfolds the need for appraising the suitability of any tree species to be involved in any environmental management program in line with the three universal questions of plantation forestry – Which tree? Where and Why? Neem has greater microclimatic effect on weather variables than *Senegalia senegal.* It also has greater edaphic impact than the latter. Therefore, it can best be used in the resolution of physical and socioeconomic crises in Sudano-Sahel Nigeria. This could probably be part of the reasons for its declaration as ***the tree of the 21st century by the United Nations*** besides multiple solutions it proffers to all global problems (World Neem foundation, 2012).

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