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Payment for Environmental Services (PES): A mechanism for adopting the agroforestry farming system among gum Arabic producers in Sudan

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Abstract

The traditional Agroforestry system is recognized as one of the successful forms of the natural resources management in the dry land of Sudan. However, field level adoption of indigenous agroforestry technology by gum Arabic producers has generally been limited due to emphasis on crop production at the expense of trees; and less supportive policy and institutional context. To encourage the adoption of the traditional system, other interventions behind regulations are needed. This paper argues for institutionalization of Payment for Environmental Services (PES) as a significant additional option for adopting the Agroforestry system among gum Arabic producers. Specifically, the paper discusses how incentive mechanisms could help address the problem of low adoption of the sustainable land management practices and, enhance the possibility for encouraging gum Arabic producers to adopt the agri-environmental farming system that offer them direct benefits and at the same time contributing to reduction of green house gas emissions. Policy interventions including targeted incentives for agri-environmental farming system; mitigating financial vulnerability and extension are highly recommended.

Keywords: PES; adoption; agro-environnemental; gum Arabic; Sudan

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1. Introduction

Acacia trees which yield the gum Arabic occur in a belt 300 km wide known as the gum belt. It is extends through the southern frontier of the Sub-Sahara Africa, from Mauritania to Sudan, Ethiopia, and Somalia and extends south words to Mozambique along the southern coast of Africa (Nas, 1979; Ross, 1968). In the Sudan the term gum belt applies to that part of country in which various types of gum are produced, the most important of these being gum Arabic. Acacia trees that produce gum Arabic is use to be a key component of the production systems within the study area. However, the drought which struck the area during the last decades affected to a large extent the ecological balance leading to the disintegration of these production systems and increased desertification affecting the regenerative capacity of land (UNSO, 1986).

Over the years, environmental degradation with special reference to the gum belt is stressed by IIED & IES in 1990, which states that: signs of environmental degradation in the central rainfed land of Sudan, including the gum belt areas, were identified as early as 1935. Environmental degradation in the gum belt area is brought about by the process of desertification, either due to climatic aridization of the environment or to anthropogenic causes. The whole belt is experiencing environmental degradation at an alarming rate. Almost the entire country, including the gum belt, is within the boundaries of arid and semi-arid climatic zones which are subject to degradation due to the prevailing pattern of rainfall. Throughout the zones, rainfall is characterized by irregularity, uncertainty and wide variability in amount, time and distribution. As a consequence of desertification; large areas become completely bare and subject to wind erosion. These include cultivation fields, settlements, roads and livestock trails. Moreover, in some areas active dunes have already formed and surrounded village and agricultural land. A watershed area which produces about 40% of vegetable production to nearest towns is one of the most threatened areas by active dunes. Agricultural production has shown continuous decline in the past 20 years. Millet and sesame are particularly susceptible to such wind erosion. This often forces farmers to bear cost of replanting.

North Kordofan in Western Sudan is one of the states which is most affected by successive droughts and desertification which led to decline in crop production per unit area. This forced farmers to follow different strategies to compensate for this decline. Some farmers had to sell all their animals and valuable savings (Jewelry); others migrated seeking job opportunities elsewhere. Those who stayed in the villages had to live partially on relief aid distributed by CARE, SCF and others NGOs, or selling forestry products such as firewood causing more de-vegetation and making the situation even worse. Drought also affected trees ability to survive. Large areas of *Acacia Senegal* and other species died in the northern parts of Kordofan as a result of moisture stress (UNSO, 1994). It could be concluded that drought has a significant effect on the productivity of pastures and tree cover, which lead to more de-vegetation and consequently desertification.

2. Agroforestry farming systems

2.1. Shifting cultivation

Shifting cultivation was a common and popular farming system in the study area. Farmers adopted shifting cultivation as a soil fertility maintenance strategy. A farmer continuously cultivates a piece of land, until the yields drop to uneconomical levels. Then he/she leaves it for some period to regenerates its fertility and shifts to another place which has been lying fallow since its last period of cultivation. This fallow period varies from area to area, from village to village in the same area and from farmer to farmer in the same village. Two factors affect the period of continuous cultivation and/or fallow. These are the population density of an area and the soil type. Generally areas with higher population are characterized by longer periods of continuous cultivation thereby shortening the fallow period. On the other hand, areas with less fertile soils experience only shorter periods of continuous cultivation as a result of which the fallow periods may be comparatively longer. The period of years under continuous cultivation in the heavy population generally varies from 4 to 8 years according to the land-use pressure of the area. Scarcity of water supplies, which forces the farmer to concentrate around water points are determined by the population density in the study area.

2.2. Fallow system and the gum cultivation cycle

The *Hashab* trees play the key role in these balance agricultural fallow systems in the study area. This tree is not only a source of income to the farmers, but it is also beneficial from the point of view of soil conservation. *Hashab* being a legume has nitrogen fixing in the soil thereby, helping to regenerate soil fertility. Moreover *hashab* stabilizes sand dunes and minimizes wind erosion. It provides an efficient wind-brake, and its roots help to hold soil particles together.

At the crop harvest, the *hashab* plots provide supplementary employment and income to the farmers, who tap the *hashab* for gum. His or her domestic animals can browse on the tender twigs of the old trees and graze on the grasses and weeds between them. The old plot when finally cleared to give way to crops, provide him with utility and cash in the form of building poles, hand tools and firewood.

The first step in the system is the cleaning of the land from the old gum tree for cultivation of crops such as millet, sorghum, sesame, and other crops. Trees are cut close to the ground so that they can produce coppice shoots later; small seedling could also be cut if overstocking is to be avoided. When the seedlings or stumps give shoots they will be cut back during the weeding operations every year for up to 4-6 year of crop cultivation period. The soil will then be left fallow to give the old stumps and seedlings the opportunity to grow vigorously and uniformly to form a stand of *Acacia senegal* on the abandoned plots (Figure 1).

Direct sowing has also been used, where farmers sow *hashab* seeds with their crops and keep cultivating the same plots until the soil is exhausted. By the time, the *hashab* trees would be 4 or 5 years old and will form a gum garden soon after the plot is abandoned. Each farmer has some gum orchards for cash crop, and some cultivated fields for his subsistence crops. However, the system is now under serious disturbance due to the occurrence of periodic drought coupled with harmful human activities.

A large peasant farmer population engaged in crop, livestock and forest production occupied the study area in Northern Kordofan State. This region was self sufficient in food grains such as millet and sorghum as well as edible oils, meat and milk. For a certain period, this region even produced a surplus that provided food to the more densely populated areas in Sudan (Palmeri, 1989). Kordofan contributed to an improved foreign exchange balance by providing cash through the export of groundnuts, sesame, hibiscus, livestock and hides (El-Tahir, 1996). However, since the drought period in the 1970s, the region has experienced a series of consecutive droughts (1969-75; 1983-86 & 1994-95). The consequences of these are desertification and deterioration of natural resources. Soil erosion and the creeping desert are hindering successful crop production and natural regeneration, aggravated by overgrazing, cutting and selling the trees as firewood and charcoal. Gum producing trees have suffered from land degradation. The reported reduction in the area of *hashab* gardens is 63% from 1960s to 1970s and to 62% reduction from the 1970s to the late 1980s and early 1990s (Chikamai, 1996). The area of *hashab* gardens per household has also reduced, from 32 hectares of gum garden per household during the 1960's, to 12 hectares during 1970's and to 9 hectares during the 1980's and 1990's for the same number of correspondent households (El Dukheri, 1997; Taha, 2000) and an average of only 7 hectares in 2005 (Elhadi, 2009). The reduction of *hashab* stock is caused on by cutting and selling the trees as wood or charcoal, and on the other hand by the expansion of area of field crops at the expense of forest lands.

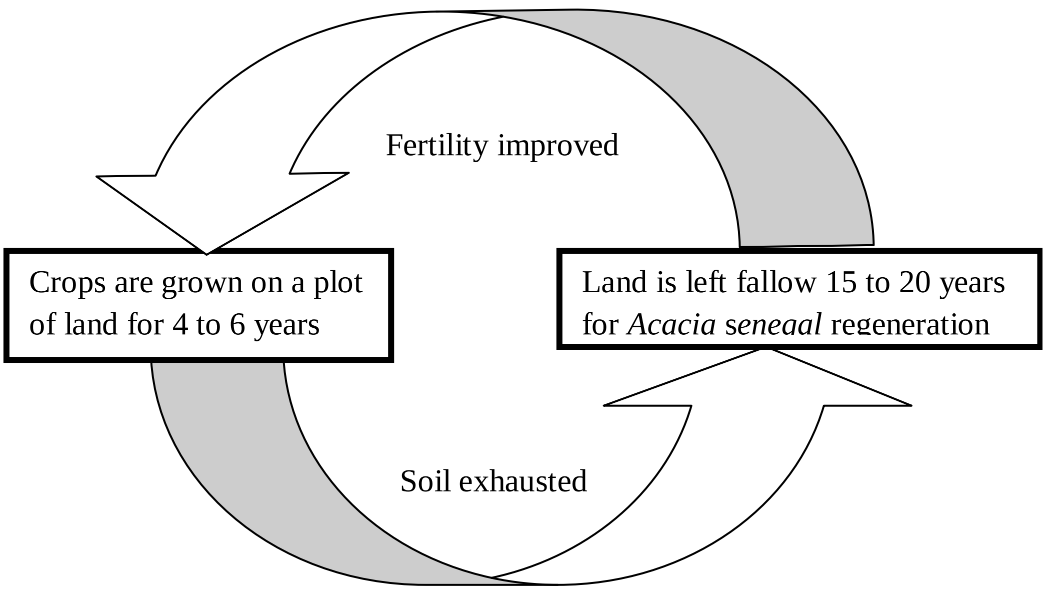

Figure 1. Bush-fallow system in North Kordofan State, Sudan (Source: Elhadi, 2009)

Gum production in Sudan also dropped due to the drought of the early 1970's to half of what it used to be in 1960's and to more than half in 1984 drought (IIED & IES, 1990). Desertification and drought have contributed to shift in the gum belt to the south. Now you can hardly find any *hashab* left north of latitude 14° 45´ in Kordofan or Darfur and the areas south of latitude 13° 45´ lost about 80% of their hashab. The situation in Northern Kordofan where gum Arabic is produced by a system of shifting cultivation was most ecologically sound. This system has not been sustainable as a result of population pressure and the resulting increased demand of land for both cultivation and human settlement. This has led to the shortening of fallow period and increase continuous cultivation of fields for several years. The study survey showed that only

20% of respondent practicing shifting cultivation where as 80% of the respondent abandons. All these problems have called for an urgent need to retain the capacity of the land to produce food crops, combat desertification and rapid deterioration of natural resources. A readily available solution to the above problem was in the use of *Acacia senegal* for reforestation which, has proved to be effective in this respect in an improved farming system in the area, minimizing the wind and water erosion while keeping the basic features of the traditional Agroforestry system in the study area.

Sudan has endeavored to get support for execution of some projects to combat desertification. The Restocking of Gum Belt Project began in 1981 with the aims of combating desertification and rehabilitating the deteriorated gum gardens within the gum belt in the area. The project has addressed desertification control through the development of central nurseries for production and distribution of *hashab* seedlings to farmers. Despite this and other efforts conducted by SOS Sahel, CARE and other NGOs, the problem of land degradation in the area had intensified, as confirmed by the United Nations Environment Program and FAO (UNDP, 2002; FAO, 2005). However, the evaluation noted some "local examples of success". Accordingly, this study seeks to answer the following questions:

- How could the farmers be effectively encouraged to returns *hashab* trees as a component of the farm household cropping system? and,
- Whether, PES could be a mechanism or instrument to re-integrate the *hashab* tree in their households' cropping system for environmental conservation?

3. Methodology of the study

3.1. Sources of data collection

This study was carried out in the North Kordofan State, Western Sudan. This area is inhabited by a number of villages practicing farming. The farm households perform economics activities that combine crop farming, livestock raising and gum production.

Sample size of 20 villages and 173 households were selected using a simple random technique. Field surveys, using structured questionnaire, informal discussions with farmers and key informant as well as visits to relevant markets constitutes the primary data set.

The cost benefit analysis techniques are used to assess the financial profitability of gum Arabic reforestation practices, where the present value of the net benefits will be achieved through discounting the project benefits (B) and Costs (C) streams with reference to project or a policy base year. The project or a policy with negative NPV will be rejected while those with positive NPV will be accepted (John et al., 1997).

$$NPV = \sum_{t=1}^{n} \frac{B_t - C_t}{(1+r)^t}$$

The analyses were undertaken for gum Arabic reforestation in an area of one hectare. The average rotation period of the gum tree was found to be sixteen years. The rate of stocking was 175 trees per hectare and the average gum production per tree estimated at 250 grams, starting from the 5th year.

4. Results and discussion

Due to the importance of the primary producer (i.e. the farmer) in the present study, Cost Benefit Analysis (CBA) from the farmer's point of view (farmer's level) were carried out. Farmer's gross benefit is the income from sales of crops at the local market where the gross costs are those incurred by the farmer only.

Most of the information presented here was collected during the field work by interviewing the farmers, forestry officers and gum merchants directly. The monetary values of outputs depended on the prices of units of outputs prevailing in their markets. Due to the importance of the primary producer (i.e. the farmer) in the present study, Cost Benefit Analysis (CBA) from the farmer's point of view (farmer's level) was carried out. Farmer's gross benefits are the income from sales of crops at the local market where the gross costs are those incurred by the farmer only.

4.1. Farmer's output

The farmers usually grow trees alongside agricultural crops. The main crops are sesame and groundnuts as cash crops, while millet and sorghum are partly cash crops but constitute the main food consumed by the farmer's household. The type of farming is the traditional rain-fed farming system which is marked by low yields and enjoys relatively lower costs of production. This is due to the absence of the use of modern inputs such as tractors, fertilizers and herbicides. As mentioned before, the ideal rotational system that ensures sustained yields of gum and agricultural crops is under serious disturbance because of the desertification. During the study survey the average farm size was found to be about 21 hectare divided as shown in Table 1.

Table 1. Major crops cultivated in the bush-fallow system and their areas in North Kordofan State, Sudan

Crop	Area (hectare)	% of total area
Gum Arabic	7.476	35.77
Millet	3.884	18.58
Sorghum	3.047	14.58
Groundnuts	0.560	02.68
Sesame	4.188	20.04
Hibiscus	1.745	08.35
Total	20.9	100%

4.2. Gum Arabic production

Basis on the field survey data, production of gum starts in the 5th year and continues up to the sixteenth. The rate of stocking is 175 trees per *Mukhamas*[1] (233.3 trees per hectare). The average gum production per tree estimated at 250 grams and the average gum Arabic producer price is estimated to be 6.75 SDG/ kg. Assuming no yield decline, gum Arabic productivity/ha will amount to 58.33kg /ha resulting in total revenue of 393.9/ha.

4.3. Firewood production at year of felling

The direct products of *hashab* are gum Arabic and wood. The stocked stand of *hashab*, 233 trees /hectare is expected to produce after sixteen years 9.33 m^3 firewood (All wood is assumed to be used as firewood). The firewood price is estimated to be 250 SDG/. Thus, per hectare firewood revenue in the year sixteen is amounted to be 2333.3 SDG.

The firewood revenue in year sixteen per hectare = 23333.33 SDG/hectare

4.4. Farm costs

In the present traditional system, the cost of cultivating *hashab* is low because land preparation and weeding impose no costs since this is done for agricultural crops anyway. The farm costs include the following cost items: labor; transportation from farm to market; tools used for gum production; trees felling (*sunki* and axes); gum collection; seeds and seedlings; and land as well as taxes. The labor cost include the cost of tapping, collection in addition to the cost of tree felling after a 16 year age given on the Table 2.

Table 2. Gum Arabic Production Costs in North Kordofan State, Sudan (SDG/ha)

Operation	Manday/ha.	Wage/Manday (SDG)	Cost SGD/hectare
Labor			
Tapping	3.33	40	133.3
Collection	2.67	40	106.6
Tree felling	4.67	20	093.3
Transportation			19.695
Tools (Sunki & Axes)			22.812
Firewood tools			20.000
Sacks			19.700
Seedling			22.812
Land rent			73.157
Taxes			51.200

Source: Based on information given by farmers (2005)

[1] *Mukhamas*: a local unit for area measurement, equivalent to 0.75 hectare.

Costs of gum Arabic transportation from farm to the market =15.0 SDG/kantar

Cost/hectare[2] = 1.313 X 150 = 196.95 SDG/hectare

Cost of tools used for gum production (*sunki* and axes) was stated by the farmers to be 22.812 SDG per hectare. The tools would, roughly, be replaced every five years. The cost of tools used for firewood production (axes) in year 16th was stated by the farmers to be 20.00 SDG per hectare. In the study area, only jute sacks are used for gum collecting. Each sack is used on average three times before a new one is purchased. One sack can take 2 kantar of gum Arabic.

The local price of jute sacks used for gum product = 30 SDG. I.e. one kantar requires 15 SDG

Thus, The cost of sacks per hectare = 1.313 X 150 = 19.695 SDG

The cost of seeds or/and seedlings require / hectare = 22.812 SDG, which include both seedlings establishment and plantation

In the study area, land is mostly free of charge as declared by most of the respondents (gum producers), although some other land tenure arrangement (share cropping, *tugundi*, hiring or renting) are also applied. According to Monke and Pearson, 1989, the market value of land is the annual cost, or rent of land itself. Therefore, the rental value of the land in at the time of data collection (73.157SDG/ha) is used as land price in the financial analysis. Taxes include direct tax, indirect tax, religious tax (*Zakat*) and regional fees were estimated at about 51.2 SDG

4.5. Financial profitability of gum Arabic production

The financial analysis assumes that gum production as part of a bush-fallow rotation system has to be established by re-planting in the area, and the hashab trees are beginning production at the age of 5 years and they are cut down for firewood after their 16th year, presented in Table 3.

The calculation of financial NPV of gum production assumes constant yield throughout the 16 years of rotation period (production per tree 250 grams) at 12 % discount rate, shows a positive financial net present value (NPV = SDG 25.837). The internal rate of return (IRR) which is the discounting rate at which the net present value (NPV) is equal to zero = 12.7% (Table 3).

In spite of the positive NPV, the discounted net income is negative from the 1st to the 15th year of the *hashab* rotation period.

These negative net benefits are a result of their annual revenues which are less than their annual costs. This result could be explained by the poor producers' price, which reflected in low producers' revenue. The net benefit turns positive in the 16th year when the value of firewood was included. This result is augmented by another result, that show the farmers could earn up to three times more per hectare from firewood and charcoal production than from gum Arabic which causes farmers to shift from reforestation of *hashab* for gum Arabic production, to *hashab* tree cutting for charcoal production. However, these financial returns from gum Arabic offer no guarantee that the farmer will in facts, undertake gum Arabic reforestation. This decision will also depend on what returns farmers obtained from other crops and the time profile of these returns.

[2] 1 hectare produced 1.313 kantar of gum Arabic

Most of the gum Arabic producer in the study area are relatively poor and may prefer the immediate financial returns offer by annual crops.

Table 3. Gum Arabic in North Kordofan: Total Revenue, Cost, Net Income, Net Present Value (NPV) and Internal Rate of Return (IRR)

Years	Total revenue	Total cost	Net income
1st	0	95.969	-95.969
2nd	0	73.157	-73.157
3rd	0	73.157	-73.157
4th	0	73.157	-73.157
5th	393.9	446.564	-52.664
6th	393.9	404.057	-10.157
7th	393.9	404.057	-10.157
8th	393.9	423.752	-29.852
9th	393.9	404.057	-10.157
10th	393.9	426.869	-32.969
11th	393.9	423.752	-29.852
12th	393.9	404.057	-10.157
13th	393.9	404.057	-10.157
14th	393.9	423.752	-29.852
15th	393.9	426.869	-32.969
16th	2727.233	520.202	2207.031
NPV (12% d. r.)*			**25.837**
IRR			**12.7**

** d. r. (discount rate) = Interest rate of the Central Bank of Sudan*

4.6. Financial profitability of other major crops in the system

Other than gum Arabic production, farmers in the study area practicing crop farming under the traditional fallow rotation system. Millet and sorghum acquired priority to meet household food needs as the main staple food crops while groundnuts for domestic oil market and export and sesame and hibiscus are produced as cash crops. No yield decline is assumed for all crops, as the bush-fallow rotation is expected to maintain soil fertility, the financial profitability per hectare of field crops using 12% interest rate, is displayed in Table 4.

Table 4. Financial profitability per hectare of major crops in the study area (SDG/ha)

Crops	Total costs	Total revenue	Net income	NPV at 12% I.R*
Millet	1055.527	874.590	- 180.937	- 1261.852
Sorghum	1066.797	1076.00	+9.203	+ 64.182
Sesame	1027.307	1056.06	+ 28.753	+ 200.523
Groundnuts	1600.527	2292.00	+ 691.473	+ 4822.323
Hibiscus	3298.101	3422.465	+ 124.364	+ 867.313
Total NPV				+ 4692.489

**I.R. = Interest rate of the Central Bank of Sudan*

Table 4 shows the financial profitability analysis of major substitute crops which are analyzed in isolation, whereas farmers actually cultivate multi-crop farming systems. The analysis indicates that Groundnuts production was extremely profitable SDG 4822.323 fallowed by hibiscus SDG 867.313, sesame SDG 200.523 and sorghum SDG 64.182 while millet production acquired losses (NPV = SDG -12618.52). The farmers in this area growing millet and sorghum crops despite its low financial returns comparing to other field crops to meet subsistence needs and food to hired labor, where losses could be subsidized from their more profitable cash crops. In fact millet crop subjected to the effect of pests, locus and birds frequently as well as stressful climatic conditions.

In conclusion, the financial analysis of crops in bush-fallow rotation systems shows that the financial returns from growing crops such as groundnuts, sesame, hibiscus and sorghum are substantially higher on a per hectare basis than for gum Arabic. However, this does not necessarily imply that land under the gum Arabic trees should be shifted to cultivate the field crops, because this profitability cannot be sustainable without fallow rotation period with gum trees, whereas rotation with gum trees helps to maintain soil fertility and water retention. Moreover, *hashab* trees providing cash income to farmers outside the growing season for other crops.

4.7. Sensitivity analysis

To argue for the payment of *hashab* reforestation as importance agri-environmental system sensitivity analysis was performed by changing the values of important variables at specific levels and observing the impact of the changes on farmer's profitability. Profitability is examined under difference scenarios;

- SCI: gum Arabic farmer price is assumed to increase by 5% and 10%.
- SC2, all inputs require for gum trees replanting are assumed to be subsidized at 5% and 10%.

- SC3: Applying different interest rates such as 8, 10, 12, 15 and 17 percent Table 5 shows the NPV and IRR using Sc1 and SC3.

Table 5. Influence of 5% and 10% increase of producer's prices and inputs subsidized on NPV and IRR of gum tree replanting in the study area

	Gum price increase by:		All inputs subsidized at:	
	5%	10%	5%	10%
NPV	163.190	297.317	121.021	216.385
IRR	17.07	23.32	15.38	18.31

It can be seen from the table that the gum replanting as a measure for combating desertification is sensitive to both Sc1 and SC2. However, (SC1) the assumed increase in the gum arabic producer price (5% and 10 %), caused a significant increase in the financial profitability of gum arabic production (NPVs increased 6.3 and 11.5 times respectively). Whereas, when the inputs subsidized at the same percentages, the NPVs of gum Arabic increased by 4.7 and 8.4 times respectively compared to the actual NPV. This profitability exceeded the profitability of cash crops in the bush-fallow system (i.e. sesame and hibiscus). The results indicate that if the determined floor price of gum Arabic was raised to SDG 315 or SDG 330 per kantar (5% or 10% respectively) instead of SDG 300, it will be remunerative and sufficient incentive to re-establish gum production in the study areas. On the other hand the discount rates at zero NPV increased to 17.07 and 23.32 when gum prices increased by 5% and 10% correspondingly, while it increased to 15.38 and 18.31 when input subsidizes at 5% and 10% respectively.

The gum Arabic profitability is also calculated at different discount rates (8, 10, 12, 15 and 17 percent), which are amounted to 255, 120, -66 and -105 respectively.

It can be noticed the NPVs of gum Arabic replanting are shown positively high returns at interest rates of 8 and 10% with 16 years rotation. When 15 and 17% interest rates are applied, NPVs show negative sign. The results indicate that if farmers borrow money from the formal sector (Central Bank or Agricultural Bank or other sectors) that normally offer interest rates of 10% or less annually, gum belt replanting as a measures for combating desertification and environmental conservation acquired high profitability to the framers compared to other crops produced in the region.

4.8. Valuing of nitrogen fixation by hashab trees

The value of nitrogen fixation as one of environmental effects of *hashab* trees on land quality in the gum belt of the Sudan calculated based on the following:

Firstly *hashab* trees provide an amount of nitrogen estimated as 770 part per million (Hussein, 1983), i.e. every million measuring units of area contain 770 nitrogen units by weight. This amount of nitrogen is equivalent to 7.7 Kilograms per hectare. It can be concluded that *hashab* trees provide the soil annually with

7.7 Kilograms of nitrogen element. Secondly; the amounts of nitrogen provided by *hashab* trees were valued using current market prices of the fertiliser used in the irrigated areas to compensate for the loss in nitrogen. There are many types of fertilisers used in the irrigated sector in Sudan. The most important is the Urea (ammonia nitrate). The ammonia nitrate fertiliser contains, in addition to other element 46% nitrogen (IIES & IES, 1990; Taha, 2000). Therefore, the amount of nitrogen provided by *hashab* trees (7.7 Kg/hectare) could be available if 16.74 Kilograms of ammonia nitrate supplied (7.7 x 46 / 100).

The replacement cost approach which is advocated by Saastamoinen, 1992; Markandya, 1992 is chosen to value the environmental benefits of *hashab* trees.

The total cost of ammonia nitrate equivalent to nitrogen provided by *hashab* trees per hectare can be computed by multiplying the cost of one kilogram ammonia nitrate (76.850 SDG) by the equivalent amount of ammonia nitrate necessary to supply 7.7 Kilograms of nitrogen.

The total cost of nitrogen provided by *hashab* trees/hectare = 16.74 Kg x 76.850 SD = 1286.4 SDG

In other words, the presence of *hashab* trees can save a cost of supplying fertiliser equals to 1286.4.00 SDG/ha.

The total economic net present value (ENPV) after including the nitrogen fixation as an environmental benefits will be equal 46,49.951 SDG/ha

It is valuable to note that nitrogen fixed by this leguminous tree could encourage grassy growth for grazing of livestock. This is of value to silvo-pastoral sedentary farming systems as well as to some nomadic systems in the area as reported by Pearce, 1990.

5. Conclusion and recommendations

The financial analysis of *hashab* replanted shows a positive return at 12% discount rate. In spite of the positive NPV, the discounted net income was negative from the 1st to the 15th year of *hashab* rotation period. This result explained by the poor producers' price, which reflected in low producers' revenue. With addition of benefits from firewood in the 16th year of rotation, the net income turns positive. The low producers' prices and low production fees on firewood and charcoal production, resulted in development of firewood and charcoal markets which contributed to more deforestation in the area. However this positive financial return, offer no guarantee that the farmer will undertake gum Arabic production within the availability of others alternative land use such as growing groundnuts, sesame, hibiscus and sorghum.

Results of the sensitivity analysis show that reforestation using gum trees is sensitive to the increase in the gum price as well as to the input subsidize by 5% or 10%, which could encourage the farmers to adopt reforestation using *hashab* trees as an available measure for combating desertification and environmental conservation.

The valuation of nitrogen fixation exhibit that the present of gum trees in the farm can save a cost of supplying fertilizer equals to SDG 12,86.400 / ha.

Based on the findings of the study the following recommendations are suggested

- Maintaining the producer price for gum Arabic is crucial to ensuring that the farmers have appropriate incentives to rehabilitate gum belt area; otherwise, other land uses such as groundnuts and sesame cultivation and firewood production may appear more attractive.
- Credit system implemented by the Agricultural Bank of Sudan is limited to certain areas and is in favor of other agricultural cash crops such as sesame and groundnuts which encouraged farmers to clear large areas of trees to plant these crops. Income support to gum farmers in form of credit would encourage preservation of gum gardens and slow down rapid deforestation. Accordingly credit should be made applicable to the farming system and should be modified to reward and motivate agri-environmental systems and cater for the needs of small-scale farmers enterprises.
- To encourage farmers to preserve the gum tree as a component of the household farming system, intervention should seek to improve returns from the gum tree through seeds and seedlings subsidies.
- The extension services is the most important channel where farmers can get information and technical assistance that will help them and increase their awareness and recognize the problem of desertification as well as the environmental and economic benefits from gum Arabic re-planting. Therefore improvement of extension services is urgently needed.
- The lack of agro-ecological and biological data has made the indirect benefits of hashab trees such as soil stabilization, water retention, stabilizing the CO_2 and dune fixation impossible to measure or to determine. However, further research into these indirect environmental effects is needed to be support.

References

Chikami, B.N. (1996), "A Review of Production, Markets and Quality Control of Gum Arabic in Africa", Paper from Mission Report, By: E. Casadi, J.J.W. Coppeb, H. O. Abdel Nour and D. Cesareo. FAO-Rome.

El Dukheri, I.A. (1997), "Past Changes and Future Prospects of Traditional Rainfed Farming in North Kordofan State", Ph. D. Dissertation, Technical University of Munich, Germany.

Elhadi, H. (2009), *Evaluation of Gum Arabic Reforestation as a measure for Combating Desertification in the Gum Belt Area of Sudan*, Margraf Publishers, Vol. 103, Weikersheim, Germany.

El Tahir, I.H. (1996), "The Suitability of Five Tree Species and one Grass for the Sudanese Arid Conditions", Master Dissertation, University of Khartoum, Sudan.

FAO, (2005), *Forest Resource Assessment*, FAO, Rome.

Hussein, S.G. (1983), "A Preliminary Study of Soils under *Acacia Senegal* (L) Wild", In: *Sudan Silva* No. 25 Vol. V. Khartoum, Sudan.

IIED and IED (1990), "Gum Arabic Rehabilitation in the Republic of Sudan", Stage 1 Report. Vol. 2. Main Report and Recommendations for Action. by: International Institute for Environment and Development London, England and Institute for Environmental Studies, University of Khartoum, Sudan.

John, A., Paul, B. and Richard, A. (1997), *Economic Analysis of Environmental Impacts*, London: Earthscan Publications Limited.

Monke, E.A. and Pearson, S.R. (1989), *The Policy Analysis Matrix for Agricultural Development*, Cornell University Press, Ithaca.

Markandya (1992), “The Value of the Environment: A State of the Art Survey”, Chapter 11 in Anil Markandya and J Richardson (eds.), The Earthscan Reader in Environmental Economics, Earthscan, London.

Nas. (1979), “Tropical Legumes,” Resources for the Future, National Academy of Science, Washington, D.C.

Pearce, D.W. (1990), “Natural Resource Management and Anti Desertification Policy in the Sahel Sudan Zone”, A Case Study of Gum Arabic, *Geographical Journal.*

Palmeri, P. (1989), “Restocking Kordofan Gum Belt”, The Sociological Aspects of the Project Area.

Ross, J.H. (1968), “Acacia Senegal (L.) Willd. In Africa, with Particular Reference to Natal”, *Sociedade Broteriana, Boletim Ser.,* Vol. 2, No. 42, pp. 207–240.

Saastamoinen, O. (1992), “Economic Evaluation of Biodiversity Values of Dipterocarp Forests in the Philippines”, Second Meeting of the International Society of Ecological Economics (ISEE), Vol.3, No.6.

Taha, M. (2000), “The Socio-Economic Role of *Acacia Senegal* Tree in Sustainable Development of Rural Areas in the Gum Belt – Sudan”.

UNSO (1986), “Restocking of Gum Belt for Desertification Control Phase II”, Mission Report, Geneva and New York.

UNSO (1994), “Restocking of Gum Belt for Desertification Control Phase II”, Mission Report, Geneva and New York.

UNDP (2002), “A New UNDP Integrated Dry Lands Development Programme”, Vol.1, Programme Framework.