

Factors Affecting Adoption of Agroforestry Farming System as a Mean for Sustainable Agricultural Development and Environment Conservation in Arid Areas of Northern Kordofan State, Sudan

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Abstract

Arid and semi-arid areas represent about 60 percent of Sudan total area. One of the main environmental problems in the arid and semi-arid areas is desertification which reduces the natural potential of the already fragile ecosystems and renders rural people vulnerable to food shortages, the vagaries of weather and natural disasters. Deforestation which is considered one of the most critical environmental problems facing the world is one of the main causes of desertification. Between the years 1990 and 2005 Sudan lost about 8.8 millions hectares of forests, which represents 11%, of its forests mainly because of subsistence activities such as overgrazing, trees cutting and expansion of traditional agriculture. One of the areas that are very much affected by desertification is Northern Kordofan State. To rescue the situation the government of Sudan, with assistance from the United Nations Development Program (UNDP) and some donors, implemented a project that aimed primarily at restocking Acacia Senegal trees in Northern Kordofan State. This study is intended to explore the factors that caused differential rate of farmers' adoption rate of the Acacia Senegal based agroforestry farming system. The study data was collected from a clustered random sample of 300 farmers, through face to face interviews using a questionnaire that was pre-tested and validated. Frequency distribution and multiple regression analysis were used to analyze the data. It has been found that farmers' adoption of agroforestry farming system in Northern Kordofan state was significantly affected by the farmers' level of formal education, contact with extension agents, level of environmental awareness, cosmopolitanism, total area of owned land and extent of social participation.

Introduction

Arid and semi-arid areas represent about 55 percent of the land surface of Africa (FAO, 2007a). In Sudan arid and semi-arid zone constitutes about 60% of the country total area, extending between latitudes 10 and 17 north (Mohamed Khair, 1994). These areas are characterized by annual rainfalls of less than 100 mm to 600 mm in a short season of 2-4 months and it varies widely from year to year with more than 50% inter-annual variability (Sharma, No Date), and its distribution within each year is also variable. Frequent winds and hot temperature aggravate the effect of variable low rainfall and the whole complex results in a fragile ecosystem which is economically and environmentally disadvantaged. One of the main environmental problems in the arid and semi-arid

areas is desertification which reduces the natural potential of the already fragile ecosystems and renders rural people vulnerable to food shortages, the vagaries of weather and natural disasters. Desertification has very detrimental and negative socioeconomic and environmental consequences. It impoverishes the natural potential of ecosystems causing reduction in agricultural yields and making it less predictable. This leads to food insecurity and causes people in affected areas to develop survival strategies which reinforce and perpetuate desertification and impede development. Moreover, desertification reduces biodiversity as it contributes to the destruction of the habitats of animals and vegetal species and micro-organisms. Thus, it furthers the genetic erosion of plant varieties and species living in these fragile ecosystems.

On the other hand, it has been observed that the survival attitudes caused by desertification have encouraged the development of local people consciousness about environment and its conservation (FAO, 2007a). Therefore, increasingly rural people are realizing that the fragile environment on which they depend for survival is being over-exploited, and it is necessary to rehabilitate and manage it sustainably.

Vulnerability of land to desertification is mainly due to the climate, the topography, the state of the soil, the natural vegetation, and the ways in which these resources are used. Thus, although drought and climatic disturbances can contribute significantly to the development of desertification, it is mainly caused by human activities that are inappropriate to local conditions such as overgrazing, land clearance, over-exploitation of cultivated and natural lands.

One of the main causes of desertification is deforestation which is considered one of the most critical environmental problems facing the world, with serious long-term economic and social consequences. In rural areas deforestation not only contributes to the destruction of environment, but also undermines the very foundation on which economic growth and long term prosperity depend and its catastrophic impacts are seen in loss of biodiversity, accelerating soil erosion which results in permanent loss in agricultural productivity and in advancing desertification accompanied by drought and famine (FAO, 2007b). Deforestation partially results from the competition between agriculture and forests for the use of land, with agriculture usually the winner. Because of the increasing degradation and loss of agricultural lands that result from loss of forests and trees and the felt threats to agriculture, attention has turned strongly to agroforestry to rehabilitate the damaged interface of agriculture and forests and to prevent further agricultural lands degradation (Clarke and Thaman, 2006).

Problem statement

Deforestation and desertification are considered the main environmental problems in Sudan and affect more than 60% of the country (ABD, 1994). Between the years 1990 and 2005 Sudan lost about 8.8 millions hectares of forests, which represents 11%, of its forests mainly because of subsistence activities such as overgrazing, trees cutting and expansion of traditional agriculture (Rainforests, 2007). One of the areas that are very much affected by desertification is Northern

Kordofan State which is considered one of the main areas where *Acacia Senegal* trees (locally known as Hashab trees), which are the main source of gum Arabic, are found. The traditional farming system for gum production in Northern Kordofan State is a bush – fallow where *Acacia Senegal* is rotated with field crops. This indigenous agroforestry farming system is recognized as one of the successful forms of natural forest management in the tropical dry lands (Abdel Rahim, 2006). This is because *Acacia Senegal* is a nitrogen fixing species and plays an important role in reclaiming degraded lands through the improvement of soil properties (Njiti and Galiana, 1996). Since early 1980s the indigenous agroforestry farming system witnessed an annoying disturbance because of drought and farmers emphasis on crop production at the expense of trees. It had been estimated that areas north of latitude 13.45 North in Kordofan and Darfur regions lost 80% of their *Acacia Senegal* trees and this resulted in reduction of both agricultural crops and gum Arabic (MOED, 2003; Olsson and Ardo, 2002). Thus, the sustainability of the *Acacia Senegal* based indigenous agroforestry farming system is threatened. To rescue the situation the government of Sudan, with assistance from the United Nations Development Program (UNDP) and some donors, implemented a project that aimed primarily at restocking *Acacia Senegal* trees in Northern Kordofan State. The main objective of the project was to halt desertification in the area by encouraging and assisting farmers to plant *Acacia Senegal* trees on their farms so as to rehabilitate the indigenous agroforestry farming system. This study is intended to explore the factors that caused differential rate of farmers' adoption of the *Acacia Senegal* based agroforestry farming system.

Literature Review

Although the widely spread and commonly used definition of sustainable agricultural development implies that present generations should use and take care of natural agricultural resources and the environment in a way that does not impoverish future generations (Tisdell, 1999), yet there is no consensus about a precise absolute and operationizable definition of the term. While for some, sustainable agricultural development means the ability to induce persistence and continuous progress in agricultural production, for others it implies not damaging or degrading natural resources and for them the basic challenge is how to make better use of available physical and human

resources and regenerative practices which optimally use locally available resources and natural processes such as nutrients recycling, build on biodiversity, regenerate and develop natural resources, and limit the use of external inputs of agro-chemicals, minerals and non-renewable energy (Pretty, 1998; Roling and Wagemakers, 1998). Thus, sustainable agriculture is not a simple package or model to be imposed, but a process for learning. Pretty (1998) argued that any system of food or fiber production that pursues the following farming objectives can be considered sustainable agriculture.

1. A thorough incorporation of natural processes such as nutrient recycling, nitrogen fixation, and pest – predator relationships into agricultural production processes, so ensuring profitable and efficient food production.

2. The full participation of farmers in rural areas in all processes of problem analysis, and technology development, adaptation and extension.

3. A greater productive use of local knowledge and practices, including innovative approaches not yet fully understood by scientists or widely adopted by farmers.

Moreover, it has been argued that regenerative practices would significantly increase productivity in the rainfed, complex and resource poor areas in developing countries which have so far not benefited from high external inputs technologies and are usually heavily degraded (Roling and Wagemakers, 1998). Consequently, policies proposed to achieve sustainable agricultural development may include measures to encourage various types of conservation farming such as agroforestry farming (Tisdell, 1999).

Wikipedia (the free encyclopedia) (2008) defined agroforestry as “a collective name for land use systems and practices in which woody perennials are deliberately integrated with crops and/or animals on the same land management unit. The integration can be either in a spatial mixture or in a temporal sequence. There are normally both ecological and economic interactions between woody and non-woody components in agroforestry. As the links and interactions between climate change, biodiversity loss, land and water degradation – and their effect on ecosystems and human beings – are apparent, the potential of agroforestry systems to mitigate and adapt to climate change, address land degradation and enhance biodiversity conservation is also clear. While protection of natural habitats remains the core of conservation strategies, agroforestry practices designed to improve land quality and productivity also

offer opportunities to create habitats for wild species in agricultural lands. Furthermore, the multifunctional nature of agroforestry offers a range of opportunities sustaining ecosystem functions which includes the use of live fences (to protect farms), woodlots (to produce fuel wood), and nitrogen fixing trees (to improve soil fertility, soil organic matter and physical conditions) (Ajayi, 2007). Thus, by enhancing agroforestry, the ancient practice of integrating trees on farms, the goals of agricultural development (increased crop and livestock productivity) can be more effectively aligned with biodiversity conservation, and this is considered one of the approaches that can be very useful and effective in making progress towards balancing environment and development needs (World Agroforestry Centre, 2007). This is because of its ability to contribute to food security by restoring soil fertility for food crops and production of fruits and nuts, reduce soil erosion and rainfall runoff, reduce deforestation and pressure on woodlands by providing fuelwood grown on farms, reduce emissions and enhance sinks of green house gases, provide more diverse streams of income and reduce poverty. Hence, as a dynamic, ecologically-based natural resources management system, agroforestry integrates trees on farms, diversifies and sustains production for increased socioeconomic and environmental benefits and is cited as a potential win – win land use system which provides key rehabilitation and other ecosystem services while it also improves production and generates income for land users. A recent study by Ajayi (2007) indicated that farmers in South Africa mentioned that agroforestry as a soil fertility improving technology has several advantages over minerals fertilizers. These includes: (1) It is cheaper and does not require direct cash expenses associated with mineral fertilizers; (2) its fertility effects last for more than one season; (3) it serves multiple purposes (fodder for livestock and fuel wood) in addition to improving soil fertility; (4) it improves biophysical functions (e.g., suppression of noxious weeds and softening of soils which facilitates easier weeding operation) and (5) provide opportunity for obtaining cash income from sale of tree products. On the other hand, farmers mentioned some disadvantages such as incidence of bush fires, pests problems, too much labor, long wait period, high mortality of tree seedlings, livestock browsing and it requires large land.

Literature about African agriculture proved that application of tree-based renewable soil fertility

replenishment technologies such as agroforestry in the traditional agricultural sector is more profitable than the conventional farmers' practice of continuous crop production without external fertilization, however, its adoption is affected by several factors such as the biophysical characteristics of the technology itself, the individual and household characteristics of the farmers, policies and the institutional context within which the technology is disseminated (Ajayi *et al.*, 2007; Kuntashula, *et al.*, 2004; Mekuria and Waddington, 2004). Among the factors that were found to influence African farmers' tree-based renewable soil fertility replenishment technologies adoption decision are availability of information about the technology, the technology perceived relative advantage and usefulness, perceived complexity, compatibility with farmers' previous experience and knowledge, land size and tenure (Ajayi and Katanga, 2005; Flett *et al.*, 2004; Place, 1995). Moreover, Haggblade *et al.* (2004) indicated that while economic considerations and short-term profitability of renewable soil fertility replenishment technologies generally increase the probability of its adoption, economic models alone do not fully explain farmers' adoption behavior regarding these technologies and their adoption decisions appear to be guided by their households level of resource endowments and the prevailing social context such as customs, obligations and beliefs which are highly affected by factors such as farmers' education, age, cosmopolitanism and family size.

Research method

The study area

The greater Kordofan region lies between latitudes 9.5 and 16.4 north, and between longitudes 27 and 32 East with a total area of 380000 square Km. Rural sedentary population represents 63%, the nomads 24% and only 13% are urban population. The annual rainfall in the region ranges between 150 mm in the north and 800 mm in the south. Millet, groundnuts, sesame and watermelon are the main agricultural crops grown in North kordfan region, in addition to gum Arabic and different types of livestock such as camels, cattle, sheep and goats. The study was conducted in North Kordofan state, where the Gum Arabic Restocking project was implemented. As the villages are scattered over a large area and there are no paved roads between them and transportation is very difficult, two rural councils (El Obeid and Rahad rural councils) were selected. About

thirty three villages in these two rural councils are included in the Gum Arabic Restocking project and farmers in these villages were provided with free Hashab (*Acacia Senegal*) seedlings.

Sample selection and data collection

Six villages from the villages included in the Gum Arabic Restocking project were selected randomly in each of El Obeid and Rahad rural councils. In each selected village twenty five farmers were selected randomly. Thus, a clustered random sample of 300 farmers was selected; 150 farmers in each rural council.

The data was collected through face to face interviews using a questionnaire that was pre-tested and validated. The questionnaire included questions about the farmers' socioeconomic characteristics and farming practices. Frequency distribution and multiple regression analysis were used to analyze the data using the Statistical Package for Social Science (SPSS).

Measurement of some of the theoretical concepts

1. Farmers' innovativeness of Agroforestry farming System:

Innovativeness is defined as "the degree to which an individual or other unit of adoption is relatively earlier in adopting new ideas than the other members of a system" (Rogers, 1993). In general, it is recognized that quantification of adopters' innovativeness of natural resource sustainable management practices such as agroforestry farming system is elusive since partial and incremental adoption by farmers makes precise measurement difficult (Ajayi, 2007; Franzel *et al.*, 2002). In this study farmers' level of adoption of agroforestry farming system measurement is based on Ajayi *et al.* (2003) idea of agroforestry adoption continuum on which farmers occupy positions depending on the extent to which they have taken different steps towards full adoption of the technology particularly the area of the field devoted to agroforestry. Consequently, an adoption scale that ranges from zero to 4 is used. Farmers who did not practice agroforestry were given a score of zero, those who devoted between 1% and less than 25%, 25% - less than 50%, 50% - less than 75% and 75% - 100% were given scores of one, two, three and four respectively.

2. farmers' education: Is measured by the number of years of formal education the farmer completed.

3. Contact with extension agent: The total number of

contacts the farmers had with the extension agent either by visiting the extension office or the visits made by the extension agent to the farmers either individually or in group.

4. Environmental awareness: It is measured by the total number of environmental problems mentioned by the farmers. Each environmental problem (e.g. deforestation, draught, desertification etc...) mentioned by the farmer was given a score of one.

5. Farmer's cosmopolitaness: Is measured by the total number of visits to any city that the farmer had made during the last year.

6. Social participation: It is measured by the total number of social organizations the respondents was a member in, the number of offices the respondent took in the social organizations in which he was a member and the number of voluntary activities (e.g. building of schools, mosques, nafir¹ for helping others etc...) the respondents participated in during the last year.

Results and discussion

The respondents' some socioeconomic characteristics:

Table (1) indicates that a high percentage (42.7%) of the respondents are of young age (≤ 40 years) compared to about one fifth (21.0%) who exceeded 60 years of age. According to the adoption theory this represents a good ground for the success of extension campaigns and programs that aim at dissemination and adoption of any agricultural innovations, particularly those intended for environment conservation and natural resource sustainable management, as young farmers have been found to be more innovative than their older counterparts (Rogers, 1993). On the other hand, it has been found that about two thirds (66.0%) of the respondents did not attend any formal education (table 1). Since illiterate farmers are less innovative than their literate fellows, this high rate of respondents with no formal education is expected to represent a major constraint to the efforts exerted to disseminate the agroforestry farming system and convince farmers to adopt it. While about two thirds (68%) of the respondents had small families that are composed of five or less members, only 1.3% of them had large families that consist of eleven or more members.

The effect of the family size on the farmer's adoption of agroforestry farming system is dubious and is expected to

1. A type of informal cooperation through which rural people help each others during time of hardship

Table 1. Some of the respondents' socioeconomic characteristics

socioeconomic characteristics	Frequency	Percentage
Age:		
≤ 40 years	128	42.7
41 – 60 years	109	36.3
≥ 61 years	63	21.0
Total	300	100
Years of formal education:		
No formal education	198	66.0
Primary education (1 – 4)	59	19.7
Intermediate education or higher (≥ 5)	43	14.3
Total	300	100
Family size		
Small family (≤ 5 members)	204	68.0
Medium family (6 – 10 members)	92	30.7
Large family (≥ 11 members)	4	1.3
Total	300	100
Area of land owned:		
Small farm (≤ 10 Mukhamas ¹)	54	18.0
Medium Farm (11 – 25 Mukhamas)	204	68.0
Large farm (≥ 26 Mukhamas)	42	14.0
Total	300	100

be of two folds. As the family is the source of farm labor in this part of Sudan and as adoption of agroforestry farming system demands more labor, larger families are expected to be more innovative than small families. On the other hand, as farmers depend for their food needs on their own production; large families are expected to plant fewer trees on their farms as they need to devote most of their land to production of food crops such as sorghum and millet. The majority (68%) of the farmers possess medium size farms that range between 11 – 25 Mukhamas in size. Large farms will make more land available for trees plantation and adoption of agroforestry farming system will not be perceived at the expense of household food security.

Determinants of respondents' innovativeness

The variables included in the agroforestry farming system adoption model (Table 2) explained 68.4% (R

Squared = 0.684) of the total variation in the respondents' innovativeness regarding adoption of agroforestry farming system. As adoption of agroforestry farming system is a complicated phenomenon (Ajayi, 2007; Franzel et al., 2002), this is considered a powerful regression model ($F = 55.712$; $P = 0.000$).

As expected farmer's level of formal education is the most important significant explanatory variable of the respondents' differential innovativeness. This is logical and consistent with the adoption theory and previous literature, as educated farmers usually have access to more information sources, can comprehend and benefit more from extension messages and are usually more aware about environmental problems (Rogers, 1993; Haggblade et al., 2004). The second important determinant of the farmers' agroforestry differential rate of innovativeness is the degree of their contact with the extension service. This can be through the extension agent visits to the farmers or the farmer visits to the extension office seeking information and advice. Agricultural extension is considered a type of informal adult education that is intended to enhance farmers' knowledge in certain areas and enables them to benefit from available agricultural technologies and improved practices. In this way, the extension service supplements the deficiency in the farmers' formal education. Thus, the significant positive effect of both farmers' education and contact with the agricultural extension service is consistent,

logical, expected and in line with previous literature (Ajayi et al., 2007; Kuntashula, et al., 2004; Mekuria and Waddington, 2004; Rogers, 1993). Farmers' level of environmental awareness represents the third important factor in the hypothesized agroforestry adoption model. Farmers' level of environmental awareness is expected to be influenced positively by their educational level and degree of contact with the agricultural extension service, so it is logical that its effect on the respondents' innovativeness to be positive. Thus, it is recommended that future research should use more advanced analytical models such as path analysis to divide the total effect of the exogenous variables, such as personal characteristics and policy variables, on the respondents' level of innovativeness into direct effect and indirect effect through intervening variables. This will help in understanding the causal mechanisms through which the different variables affect farmers' innovativeness which is very useful in designing extension programs for enhancing adoption of such innovations. Agricultural extension programs that aim at enhancing adoption of environment conservation innovations usually place great emphasis on raising the target population level of environmental awareness as a key factor for realizing its' objectives. This (i.e. the importance of environmental awareness) is confirmed by this study. The fourth important explanatory factors of the variation in the farmers' level of innovativeness regarding adoption of agroforestry farming

Table 2. Regression of farmers' innovativeness regarding adoption of agroforestry farming system on some independent variables.

Dependent variables	Independent variables	β value	Sig. Level
Farmers' innovativeness	Education	.364	.000
	Contact with extension agent	.209	.002
	Environmental awareness	.137	.002
	Farmer's cosmopolitanness	.117	.007
	Total area of owned land	.122	.012
	Social participation	.116	.021
	Number of family members who work in agriculture	.158	.062
	Family size	-.078	.127
	Cultivated area.	.066	.202
	No. of hired labors	.072	.428
Age	-.035	.655	

R Squared = 0.684; $F = 55.712$ ($P=0.000$)

² one Mukhamas = 0.73 hectare

system is the respondents' cosmopolitanism. Farmers' cosmopolitanism can be perceived as proxy of their openness and exposure to different sources of information which are important correlates of high level of innovativeness. The total area of owned land ranked as the 5th important significant determinant of the respondents' innovativeness. One of the main constraints of agroforestry adoption is the perception that trees compete with agricultural crops for land particularly when the size of holding is small. This perception will not hold true when the size of the farmers holding is large enough to accommodate both agricultural crops and trees. The last significant predictor of respondents' innovativeness is their degree of social participation. Since Social participation is measured by the total number of social organizations the respondents was a member in, the number of offices the respondent took in the social organizations in which he was a member and the number of voluntary activities (e.g. building of schools, mosques, nafir for helping others etc...) the respondents participated in during the last year, it can be used as a proxy for the respondents' exposure to different sources of information and socioeconomic status which are both important determinants of innovativeness.

Although the other variables included in the regression model (number of family members who work in agriculture, family size, cultivated area, No. of hired labors and age) did not have a statistically significant effect on the respondents' innovativeness, yet the sign of the regression coefficient of all of them is as expected which supports the theoretical arguments on which the adoption model is based.

Conclusion

Farmers' adoption of agroforestry farming system in Northern Kordofan state is found to be significantly affected by the farmers' level of formal education, contact with extension agents, level of environmental awareness, cosmopolitanism, total area of owned land and extent of social participation. The fact that the farmers' level of formal education, contact with extension agents and level of environmental awareness are the three most important determinants of the farmers' differential rate of innovativeness regarding adoption of agroforestry farming system reflects the important role that extension programs can play in enhancing adoption of natural resources sustainable management innovations. Moreover, it is recommended that future research in this area use more advanced analytical models such as path

analysis model to determine the causal mechanisms through which the different variables influence the adoption process so as to be able to determine the appropriate interventions and policies for enhancing farmers' innovativeness.

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العوامل المؤثرة على تبني نظام الزراعة الحراجية كوسيلة لتحقيق التنمية الزراعية المستدامة والحفاظ على البيئة في المناطق الجافة بولاية شمال كردفان – السودان

صديق الطيب منير

قسم الإرشاد الزراعي والمجتمع الريفي - كلية علوم الأغذية والزراعة - جامعة الملك سعود

الملخص

تمثل الأراضي الجافة وشبه الجافة حوالي ٦٠٪ من مساحة السودان الكلية. يعتبر التصحر أحد المشاكل البيئية الرئيسية في المناطق الجافة وشبه الجافة والتي جعلت السكان في هذا النظام البيئي الهش أكثر تأثراً بتقلبات المناخ وأشد عرضة لعدم الأمن الغذائي. ويمثل تدهور وإزالة الغابات أهم أسباب التصحر حيث فقد السودان خلال الفترة ١٩٩٠ - ٢٠٠٥م حوالي ٨,٨ مليون هكتار من الغابات، تمثل حوالي ١١٪ من مساحة الغابات، بسبب بعض الأنشطة غير الصديقة للبيئة مثل الرعي والاحتطاب الجائر والتوسع الزراعي في أراضي الغابات. تعتبر ولاية شمال كردفان من أكثر مناطق السودان تأثراً بظاهرة التصحر. ولاستعادة الغطاء النباتي في هذه المنطقة نفذت حكومة السودان بالتعاون مع برنامج الأمم المتحدة الإنمائي مشروع الزراعة الحراجية بهدف زراعة أشجار الهشاب المنتجة للصبغ العربي في الولاية. يهدف هذا البحث إلى التعرف على العوامل المحددة لتبني الزراعة في ولاية شمال كردفان لنظام الزراعة الحراجية. تم جمع البيانات عن طريق المقابلة الشخصية باستخدام الإستبانة من عينة عنقودية عشوائية مكونة من ٣٠٠ مزارعاً. أستخدم التوزيع التكراري والانحدار المتعدد لتحليل البيانات. أوضحت الدراسة أن أهم محددات تبني نظام الزراعة الحراجية هي سنوات التعليم النظامي التي أكملها المزارع، درجة اتصال المزارع بالمرشد الزراعي، مستوى وعي المزارع البيئي، اتصال المزارع بالمجتمعات الأخرى، مساحة الأرض التي يملكها المزارع ومستوى المشاركة الاجتماعية للمزارع.