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Economic Analysis of Sorghum Production under Conservation Agriculture and Conventional Farming Systems in small-scale Farms in Rainfed Areas Southern Gedarif State, Sudan

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Abstract
A project was conducted in rainfed areas southern Gedarif State, to improve sorghum productivity of small-scale farmers. The project implemented conservation agriculture (CA) in 2.1 hectares for each participated small-scale farmer during the period from 2014 to 2017. The objective of this study was to conduct economic analysis for sorghum production under conventional farming (CF) and conservation agriculture (CA). Data on production costs, yield and income of sorghum by using CA and CF systems were collected through questionnaire from small-scale farmers participated in the project for three consecutive seasons (2014 to 2016). Sixty farmers out of 150 farmers (40%) participated in the project for the three seasons were randomly interviewed, and economic indicators were used. The results showed that CA gave higher sorghum grain yield (1797 kg/ha) compared to CF (881kg/ha). Also, the total production cost was higher for CA (3963 SDG/ha) compared to the total production cost of CF (2020 SDG/ha). The costs of inputs and operations constituted the highest share of CA total cost. In addition, CA gave higher gross return (4035 SDG/ha) compared to the CF (2192.3 SDG/ha). The profit in the first two seasons was comparable for both cropping systems. The average breakeven point (BEP) was 1920 kg/ha and 971 kg/ha for CA and CF, respectively. Sensitivity analysis revealed that increasing sorghum yield by 20% the BEP decreased by 1%, whereas increasing sorghum price by 20% the BEP decreased by 16%. The sensitivity analysis revealed that net return and BEP were affected by changes in production cost and sorghum price. Moreover, CA had many positive residual effects on the performance of the crops grown in the subsequent seasons. In conclusion, CA has instantaneous and future positive impacts on small-scale farmers' livelihood and production sustainability; but it is necessary to reduce its cost.

Keywords: *Cost benefit ratio, breakeven point, sensitivity analysis, rainfed sorghum yield, small-scale farmers*

Introduction
Sorghum (*Sorghum bicolor L.*) is intensively produced in rainfed areas of the Sudan in large schemes and in small farms as well. The small-scale farmers whom their farms are scattered nearby villages usually practice sorghum production for subsistence.

Production of sorghum in the rainfed areas of Sudan is more or less the same, which uses conventional farming (CF). Generally, the CF lacks behind to improved technical packages and scientific standards for implementing farm operations. Farmers usually start to cultivate their fields when about 100 mm or more of rainfall occurs. They use the conventional machine, the wide level disk (WLD) plow with seeder box, for seedbed preparation and seeding operations. Delayed sowing date and the use of local varieties are common practices. Moreover, neither a definite rotation is followed nor fertilizers are applied. The resultant is low average yield, misuse of resources and economic loss.

There is, however, a potential and opportunities to improve the sorghum yield in rainfed areas through the use of the recommended technical packages and implementation of intelligent economic policies. The use of recommended or improved technical package not only increase the yield but also conserve the limited resources such as land and water. Many efforts were made by the governmental institutions, NGOs and private sector to change CF system in rainfed areas.

Conservation agriculture (CA), which uses improved technical packages, could be defined as resource-saving agricultural crop production that try to achieve acceptable profits together with high and sustained production levels while conserving the environment (FAO, 2007). Other practices that meet the definition of CA are zero tillage (ZT) and direct seeding. CA is usually practiced in areas which receive an annual rainfall of more than 600 mm. The advantages of CA are recognized elsewhere. The CA reduced the overall requirement for farm power and energy for field production compared to CF (Doets *et al.*, 2000; Bistayev, 2002). Additionally, CA saved 25% of fuel and 26% of time required to establish sorghum crop (Yousif and Babiker, 2015). However, several studies on sorghum yield in rainfed areas of Sudan revealed that the use of ZT or CA out yielded CF system (Taha *et al*., 2005; Yousif, *et al.,* 2009; Yousif and Babiker, 2015).

A project named Sudan food security programme-rural smallholders component (SFSP-RSC), funded by the European Union, aimed at improving sorghum productivity in small-scale farmers' farms in rainfed areas. The SFSP-RSC was conducted in some villages in the East Galabat locality in Gedarif State under the supervision of ZOA and Zenab NGOs during the period from 2014 to 2017. The implemented technical package in the small-scale farmers' farms was CA. The CA was implemented in 2.1 hectares for each participated small-scale farmer. The number of small-scale farmers increased from one year to another. The NGOs rent service providers to implement CA in farmers' farms. The service providers availed the inputs (seeds, seed treatments, fertilizers and herbicides) and executed the seeding operation and fertilizers application as well as spraying operations. No information about the effect of the implementation of this project on the small-scale farmers' income and livelihood; therefore, conducting economic analysis is of great value.

The objective of this study was to conduct economic analysis for sorghum production under CF and CA in small-scale farms southern Gedarif rainfed areas, where the SFSP-RSC was implemented.

Materials and Methods

The studied sites were the villages in East Galabat locality southern Gedarif State where ZOA and Zenab NGOs implemented the SFSP-RSC project. The primary data was collected through a structured questionnaire and direct interviews from the small-scale farmers whom practiced CA for three consecutive growing seasons (2014 to 2016). The secondary data was collected from the

project records, which included villages and number of participated small-scale farmers from each village as well as inputs and operation costs. Sixty farmers out of one hundred and fifty farmers (40%) from four villages were randomly selected. The stratified random sampling method was used as a selection procedure, and gender issue was considered in sampling. Table 1 shows the names of the studied villages, number of small-scale farmers, sample size and gender representation.

Table 1. East Galabat locality studied villages, number of participated farmers, sample size and gender representation, Gedarif State seasons 2014, 2015 and 2016

Village name	Number of participated farmers			Sample size	Number of participated women	Number of participated men
Mahala		67		27	3	24
Madug		64		25	5	20
El-Saboot		12		5	1	4
Rashid		7		3	0	3
Total	*150*	*60*	*9*	*51*		

A comprehensive and detailed data on the effect of practicing CA on the livelihood of the participated small-scale farmers was obtained. The questionnaire was designed to obtain data on yield, detailed costs (harvesting and marketing costs) and income (grain and forage) by using CA for sorghum production. Moreover, data on producing sorghum by CF was also included for comparison. Furthermore, the opinion of farmers about the residual effect of using CA on the subsequent cropping seasons was reported.

To accomplish the study objectives, descriptive statistics, cost analysis, net return, benefit cost ratio and breakeven-even-point (BEP) in addition to sensitivity analysis were used as methods of analysis.

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Results and Discussion

Sorghum yield

Figure 1 compares sorghum grain yield obtained by the surveyed small-scale farmers from CF and CA during the three seasons. The results showed that the CA gave higher yield than the CF throughout the three seasons. The overall average grain yield by using the CF and CA was 881 (kg/ha) and 1797 (kg/ha), respectively. This result is in agreement with several studies (Abdulrazak, 2006; Ismail *et al.,* 2012; Yousif and Babiker, 2015). This indicated the superiority of the CA over the CF. Geneif (2005) and Ibrahim *et al.,* (2015) stated that one of the main reasons for low yield in small-scale farms is the low level of the used technology and its application

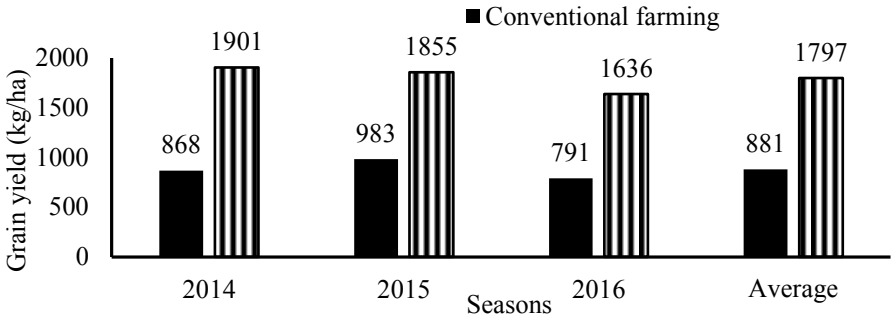

Figure 1. Sorghum grain yield (kg/ha) for conventional farming and conservation agriculture in Gedarif State for three seasons

Cost analysis

The costs (SDG/ha) of sorghum production under CF and CA were calculated based on data collected from the surveyed small-scale farmers for the three seasons. The results depicted that, as expected, the production cost of CA was high compared to the cost of the CF system for the three seasons (Fig. 2). The overall average production cost of CA was higher than the cost of CF by almost two folds. Abdulrazak (2006) found that the cost of sorghum under zero tillage was 252% over the cost of CF. Similar results were reported by Ismail *et al.* (2012). For both cropping systems, the production cost increased from season 2014 to season 2016.

On the other hand, the cost analysis for CA revealed that the cost of inputs and operations represented the biggest portion of the total production cost compared to harvesting and marketing costs (Fig. 3). This was mainly due to the high cost of agrochemicals (fertilizers and herbicides) and machineries. The harvesting cost increased with the increase of grain yield.

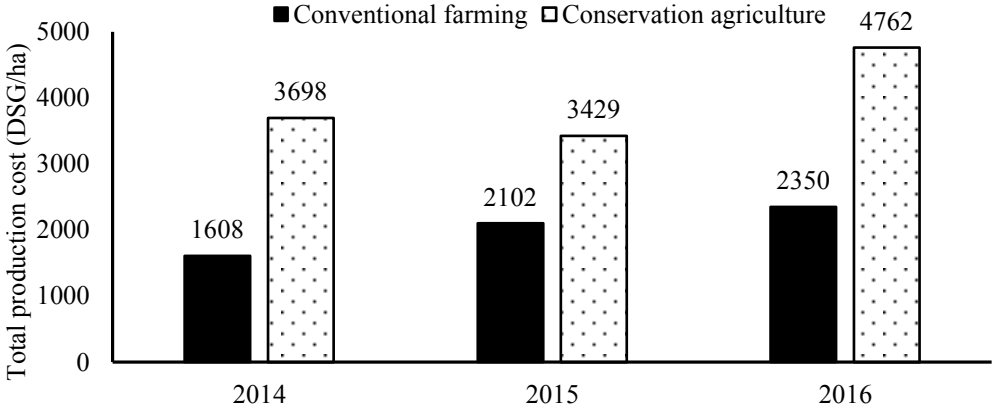

Figure 2. Total production cost for conventional farming and conservation agriculture in Gedarif State for three seasons

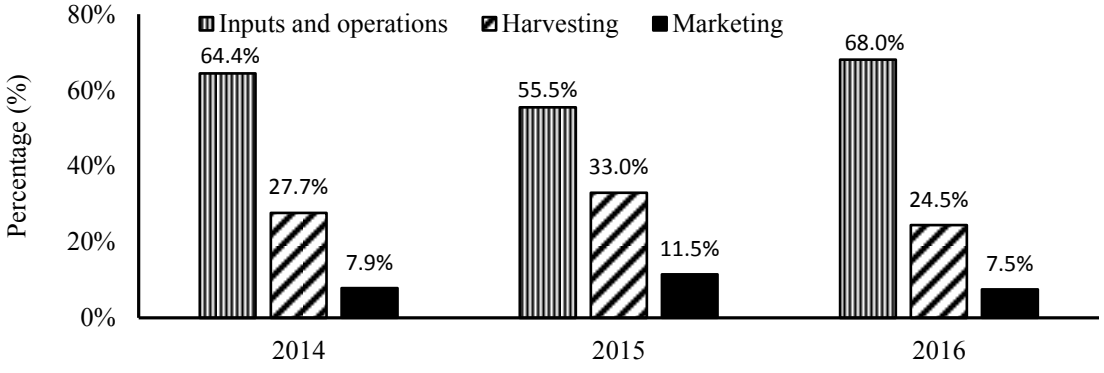

Figure 3. Percentage of main cost items from total cost of conservation agriculture in Gedarif State for three seasons

Harvesting cost represented the highest share for the total cost of the CF followed by the costs of inputs and operations while marketing cost showed the lowest share (Fig. 4). The surveyed farmers said that row planting and weed free farms in CA make sorghum harvesting easier and cheaper compared to harvesting sorghum in CF.

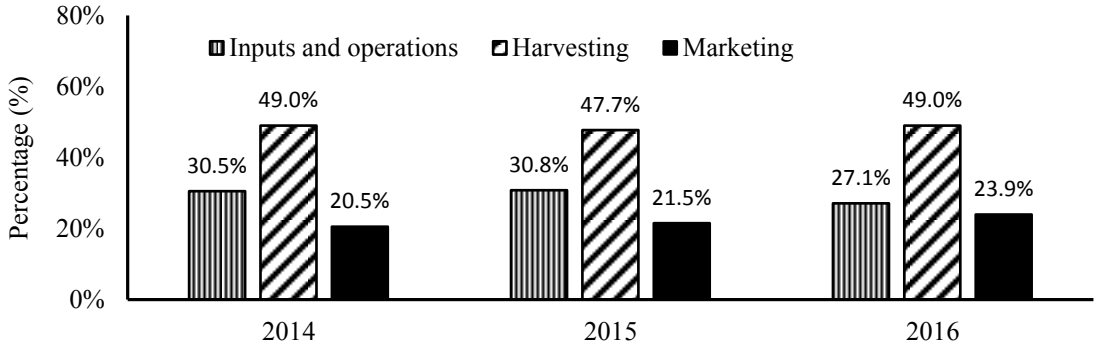

Figure 4. Percentage of main cost items from total cost of conventional farming in Gedarif State for three seasons

Economic analysis

Sorghum price fluctuated from season to another (Table 2); the highest price was in season 2015 and the lowest in season 2014. The sorghum price not increased at the same rate of total costs, this affected farmers' profit. Gross return is the summation of the return from grain and from forage. The results showed that producing sorghum by using CA gave higher gross return (4035 SDG/ha) throughout the three seasons compared to the CF (2192.3 SDG/ha). The gross return from CA was double of that of the CF throughout the three seasons. The results showed that for both cropping systems, the net return in the first two seasons was profitable but not in the third season.

Table 2. Economic analysis of sorghum production under conventional farming and conservation agriculture, Gedarif State

Item	Conventional farming (CF)			Conservation agriculture (CA)		
Season	2014	2015	2016	2014	2015	2016
Sorghum price (SDG/kg)	1.95	2.26	2.03	1.95	2.26	2.03
Grain return (SDG/ha)	1693	2222	1606	3707	4192	3321
Forage (SDG/ha)	274	427	355	330	361	248
Gross return (SDG/ha)	1967	2649	1961	4037	4553	3569
Net return (SDG/ha)	359	547	-389	339	1124	-1193

Table 3 presents that the benefit cost ratios for the CF and CA were comparable in each season. Breakeven point (BEP) is the required yield (kg/ha) to cover the total production costs, was calculated by dividing the total cost (SDG/ha) over sorghum price (SDG/kg). The results revealed that BEP was higher for CA compared to CF in the three seasons (Table 3). This was mainly due to the high production cost of CA. The average BEP was 1920 kg/ha and 971 kg/ha for CA and CF, respectively.

Table 3. Benefit cost ratio and breakeven point for sorghum production under conventional farming and conservation agriculture, Gedarif State

Item	Conventional farming (CF)			Conservation agriculture (CA)		
Season	2014	2015	2016	2014	2015	2016
Benefit cost ratio	1.2	1.3	0.8	1.1	1.3	0.8
Breakeven point (kg/ha)	825	930	1158	1896	1517	2346

On the other hand, Table 4 shows the observations of small-scale farmers about the residual effects of using CA on the performance of crops grown in the subsequent season. About 82% of the farmers said that there were positive residual effects when using the CA. They identified these positive effects as reducing weed infestation and weeding cost (59%); increasing crop productivity (29%) and increasing soil fertility (12%) as shown in Table 5. These results indicated the successful of the CA. These positive residual effects coupled with higher yield help in convincing the small-scale farmers to adopt CA.

Table 4. Farmers' opinion about the residual effect of conservation agriculture on the performance of crops grown in the subsequent season, Gedarif State

Residual effect	Frequency	(%)
Positive residual effect	49	81.7
No residual effect	11	18.3
Total	60	100

Table 5. The positive residual effects of conservation agriculture as identified and ranked by the small-scale farmers in Gedarif State, three seasons

Residual effect	Frequency	(%)
Reducing weed infestation and weeding cost	29	59.2
Increasing crop productivity	14	28.6
Increasing soil fertility	6	12.2
Total	49	100

Sensitivity analysis

Many scenarios were carried out to detect the response of CA to changes in some parameters. The effects of changing the total cost of CA without changing the yield and sorghum price on net return and BEP are shown in Table 6. Increasing the total cost by 20% profit was observed in the second season only; whereas decreasing the total cost by 20% profit was in the first and the second seasons. Increasing and decreasing the total cost increased and decreased the BEP by the same percentage in the three seasons. These results illustrate the importance of decreasing production cost.

Table 6. Effect of changing total cost of conservation agriculture on net return and breakeven point in Gedarif State, three seasons

Item	+20% of total cost			-20% of total cost		
Season	2014	2015	2016	2014	2015	2016
Total cost (SDG/ha)	4438	4115	5714	2958	2743	3809
Net return (SDG/ha)	-405	439	-1893	1074	1811	12
Breakeven point (kg/ha)	2285	1828	2833	1508	1234	1874

Table 7 shows the effect of increasing sorghum yield and price for CA on net return and BEP. The results showed that increasing sorghum yield by 20% the net return increased by 204%, 145% and 65% for seasons 2014, 2015 and 2016, respectively. On the other hand, increasing sorghum price by 20% the net return increased by 220%, 143% and 65% for the three seasons, respectively. Increasing sorghum yield by 20% decreased the BEP by 1%, whereas the increasing in sorghum price by 20% decreased the BEP by 16% from the original value. This means that yield has negligible effect and price has abundant effect on BEP.

Table 7. Effect of increasing yield and sorghum price by 20% on net return and breakeven point in of conservation agriculture in Gedarif State, three seasons

Item	Increasing yield by 20%			Increasing sorghum price by 20%		
Season	2014	2015	2016	2014	2015	2016
Total cost (SDG/ha)	3698	3429	4762	3698	3429	4762
Yield (kg/ha)	2285	2239	1965	1901	1855	1636
Price (SDG/kg)	1.95	2.26	2.03	2.34	2.71	2.44
Net return (SDG/ha)	692	1632	-771	745	1603	-774
Breakeven point (kg/ha)	1919	1508	2331	1599	1280	1965

Table 8 shows the frequency and percent of farmers whom their obtained yield equal to or exceed the BEP at different scenarios. The results revealed that at current situation (on the average) 50%, 70% and 7% of the surveyed farmers their yield covered the total cost during the three seasons, respectively. These percentages of farmers increase to 68%, 82% and 33% when the total cost is decreased by 20%. This means that decreasing production cost is necessary for profitability. On the other hand, the results showed that more farmers can cover the total cost if the sorghum price is increased by 20%. These results indicated that production cost and sorghum price affected breakeven point and thus net return.

Table 8. Percentage of farmers practiced conservation agriculture whom their yield equal to or exceed BEP at different scenarios, Gedarif State

Seasons	2014		2015		2016	
Scenarios	Freq.	%	Freq.	%	Freq.	%
Average total cost	30	50	42	70	4	7
+ 20% of total cost	19	32	34	57	1	2
- 20% of total cost	41	68	49	82	20	33
+ 20% of sorghum price	41	68	48	80	16	27

Conclusion

Producing sorghum in rainfed areas by using CA in small-scale farms gave higher yield, resulted in many positive residual effects on the performance of crops grown in the subsequent seasons and gave higher gross return throughout the three seasons compared to CF. Production cost was higher for CA compared to CF throughout the three seasons. Inputs and operation cost constituted the highest share of CA cost. For both cropping systems, the net return in the first two seasons was profitable but not in the third season. Sensitivity analysis revealed that net return and breakeven point were affected by production cost and sorghum price.

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التحليل ا قتصاديات ا نتاج ذ ة الرفيعة تحت نظامي الزراعة الحافظة و الزار ة التقليدية في حقول صغار المزار ين في المناطق ا ر ية جنوب ولاية القضارف ، السودان

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تم تنفيذ مشروع في المناطق المطرية جنوب ولاية القضارف، لتحسين إنتاجية الذرة الرفيعة في حقول المزارعين أصحاب الحيازات الصغيرة. نفذ المشروع نظام الزراعة الحافظة (CA) في مساحة 2.1 هكتار لكل مزارع من أصحاب الحيازات الصغيرة مشارك في المشروع خلال الفترة من 2014 إلى 017! . وكان الهدف من هذه الدراسة هو إجراء تحليل اقتصادي لإنتاج الذرة الرفيعة تحت نظامي الزراعة التقليدية (CF) والزراعة الحافظة (CA) . تم جمع بيانات عن التكاليف والعائد والدخل لإنتاج الذرة الرفيعة باستخدام الزراعة الحافظة ونظام الزراعة التقليدية من خلال استبيان للمزارعين أصحاب الحـ ازات الصغيرة الذين شاركوا في المشروع لمدة ثلاثة مواسم متتالية (2014 ى 016!). تمت مقابلة 60 مزارعاً عشوائياً من جملة 150 مزارعًا (0 ٪) شاركوا في المشروع لمدة ثلاثة مواسم متتالي ، واستخدمت في الدراسة بعض مؤشرات التحليل الاقتصادي. أظهرت النتائج أن الزراعة الحافظة أعطت إنتاجية عالية من حبوب الذرة الرفيعة (1797 كجم/هكتار) مقارنة الزراعة التقليدية (881 كجم/هكتار . كما كانت التكلفة الكلية للإنتاج كبيرة في نظام الزراعة الحافظة (3963 جنيه/هكتار) مقارنة بالتكلفة في نظام الزراعة التقليدية (2020 جنيه/هكتار). ، شكلت تكاليف المدخلات والعمليات الفلاحية أعلى نسبة من جملة ا تك ف الكلية لزراعة الحافظة علاوةً على ذلك أعطى نظام الزراعة الحافظة أعلى عائد إجمالي (4035 جنيه/هكتار) ، قار ة ا عائد ا جمالي من نظام الزراعة التقليدية (2192.3 جنيه/هكتار). ، كان الربح في الموسمين الأولين متشابه لكل من نظامي الإ تاج . كان متوسط نقطة التعادل (3EP) 1920 كجم/هكتار و971 كجم/هكتار لكل من نظامي الزراعة الحافظة و الزراعة التقليدي ، على التوالي. أشار تحليل الحساسية إلى أن زيادة إنتاجية الذرة في نظام الزراعة الحافظة بمعدل 0 % قلل من نقطة التعادل (3EP) بحوالي %، بينما زيادة سعر محصول الذرة بمعدل 0 % أدى لتقليل نقطة التعادل (3EP) بحوالي 6 %. كشف تحليل الحساسية تأثر كل من صافي العائد ونقطة التعادل التغير في تكلفة الإنتاج وسعر الذرة. علاوة على ك أشارت النتائج ن نظام لزراعة الحافظة العديد من الآثار الإيجابية المتبقية على أداء المحاصيل في المواسم اللاحقة (التالية . خلصت الدراسة إلى أن للزراعة الحافظة آثار إيجابية فورية ومستقبلية على معيشة المزار عيين أصحاب الحيازات الصغيرة وعلى استدامة الإنتاج ، ولكن بالضرور التقليل من تكاليفه .