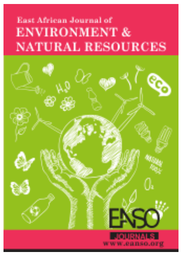

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Original Article

Cost-Benefit Implications of Conservation Agriculture with Trees in the Dry Lands of Machakos County, Kenya

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ABSTRACT

The adoption of conservation agriculture and agroforestry has been cited as the solution to the degradation and low profitability challenges in the drylands. The two systems have been known to result in high profitability through the improvement of yields and lowering of crop production costs. The study was carried out as part of ongoing experimentation established in the short rains (SR) season of 2012 by the World Agroforestry Centre in an on-station site at the Agricultural Training Centre (ATC) in Machakos County, Kenya. The trials were based on a split plot arranged in a randomised complete block design with two farming systems (conventional and conservation agriculture) serving as the main blocks, 10 treatments and three replicates, summing to a total of 60 plots. In the fields, three shrub species (*Calliandra calothyrsus* Meissn., *Cajanas cajan* (Pigeon pea), and *Gliricidia sepium* Jacq.) were planted in three different spacing (1.5 x 1 m, 3 x 1 m, 4.5 x 1 m) for maize-legume intercrops. The costs of production were recorded consistently in each season (LR 13, SR 13, and LR14). The maize and legume yields were valued at the market selling price from the local market, and a cost-benefit analysis was done through the calculation of benefit-cost ratios (BCR). The data was statistically analysed using ANOVA and means were separated using LSD at $p < 0.05$. Results showed significantly high BCR under conservation agriculture ($p < 0.0001$) in all seasons with sole CA having the highest BCR of 9.9 in LR 2014. The BCRs were lower in the first season due to high initial production costs, but this increased steadily in the succeeding seasons. The study concludes that conservation agriculture both with trees and as the sole is beneficial to the farmer, with higher net benefits compared to conventional tillage.

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INTRODUCTION

Conservation Agriculture (CA) has been claimed to be a solution for the challenges of soil degradation and poor agricultural productivity, especially in sub-Saharan Africa and has gained promotion from most research and development organisations both local and international (Giller et al., 2009; Hobbs, 2007; FAO, 2008). The hypothesis that the adoption of conservation agriculture results in higher profitability through the improvement of yields and lowering of crop production costs has been proven to be true (Hobbs et al., 2008). Stevenson et al. (2014) showed that conservation agriculture brings about significant benefits in yield, saves water and increases profits significantly. The role of conservation agriculture in the generation of environmental benefits that are socially valued has also gained acceptance (Garnett et al., 2013). The principles under which conservation agriculture operates, namely crop rotation and/or associations, minimum tillage, and maintenance of soil cover through cover crops and residue have also been proven to be very attractive from an economic and agronomic viewpoint (Thierfelder et al., 2013; Hobbs, 2007). The short-term yield effect of conservation agriculture in particular, which always tend to be positive (Corbeels et al., 2014), has been recognised as very important in influencing the adoption of CA by farmers who are always first to look for the attractiveness of any system in terms of yield improvements (Giller et al., 2009).

Despite the proven benefits, the adoption of conservation agriculture by smallholder farmers has remained low (Giller et al., 2006; Kassam et al., 2009). In fact, farmers will not consider adopting conservation agriculture in context if the long-term benefits were to be the influencing factor, especially if they are resource-poor (Scoones, 2001; Corbreels et al., 2014). The production costs of conservation agriculture, particularly labour, have been shown to be limiting too in the smallholder context where the labour is very intensive (Stevenson et al., 2014). Saving the farmers through subsidies is therefore appropriate. Conservation agriculture interventions must also be tailored to the local circumstances of farmers (Erenstein et al., 2012; Giller et al., 2011) to balance the costs and benefits and to increase their attractiveness.

Comparatively, the incorporation of trees into cropping systems (agroforestry) may be an option to confer sustainability benefits through ecological intensification (Garrity, 2011). Trees may live for many years and will thus be providing inter-generational benefits for a farm family, with modest investment implications initially (Garrity et al., 2010). Agroforestry systems have been shown to have high returns compared to single-crop farms without trees. Intercrops with *Gliricidia* and

Sesbania for instance have been found to have high Benefit-Cost Ratios (BCR) of between 2.77 to 3.13, in contrast to 2.65 in subsidised fertiliser applications and 2.01 in non-fertilised fields without trees (Ajayi et al., 2009), presenting concrete evidence of agroforestry in improving the net income of farm families. Practising both agroforestry and conservation agriculture consecutively in one system called conservation agriculture with trees (CAWT) will thus maximise the farm returns due to the double inferred benefits from the two systems (Garrity, 2011). However, there is high initial labour involved when moving from conventional practice to evergreen (CAWT) farming systems which involve trees (Wall, 2007; Garrity et al., 2010), and which may be managed efficiently once more experience is gained in the tree-based systems (Tripp, 2005). However, suggestions have been made that the high costs can be reduced through options like combining more than one fertiliser tree species in the farms and pruning the trees concurrently while weeding (Katanga et al., 2007).

MATERIALS AND METHODS

Study Area

The study was carried out at on-station demonstration plots earlier established by the International Council for Research in Agroforestry (ICRAF) at the Machakos Agricultural Training Centre at coordinates E037°14.303ˈ and S 01°32.738ˈin Machakos County. Machakos is an administrative County in Kenya and lies in the sub-humid and semi-arid eastern Kenya, covering an area of about 6,281.4 km^2 and located 64 km southeast of Nairobi city, stretching from latitudes 0^0 4´ to 1^0 31’ South and longitudes 36° 45’ to 37° 45’ east (HSK, 2005). The region experiences annual mean temperature and rainfall range of 17.7 to 24.5 °C and 700 to 1300 mm, respectively. The rainfall is bimodal with long rains (LR) from mid-March to June and short rains (SR) from late October to December hence the potential of two annual cropping seasons. The average seasonal average rainfall range is between 250 mm and 400 mm, but highly variable (coefficient of the variation range of 45% to 58 %), characterised by prolonged dry spells, frequent crop failure and high food insecurity (Kenya Agricultural Research Institute [KARI], 1997).

Experimental Design and Management

The experiment ran from Long Rains 2013 (LR 2013) to Long Rains 2014 (LR 2014). At the inception of the project, the researcher managed trials on the integration of selected leguminous shrubs (*Grilicidia sepium, Calliandra calothyrsus and Cajanas cajan* (Pigeon pea*))* into a maize-legume intercropping system under CA and Conventional agriculture (henceforth COA) was set-up at the agricultural training centre (ATC) in Machakos. The trials adopted a split plot arranged in a randomised complete block design with two main blocks on CA and COA, each with 10 treatments, replicated thrice. Thus, a total of 30 demonstration plots measuring 12 by 12 m in a randomised complete block design (RCBD) were established on each of the main blocks, summing up to 60 demonstration plots. *Gliricidia sepium, Cajanas cajan and Calliandra calothyrsus* were integrated at a different inter-row spacing of 4.5 m, 3.0 m, or 1.5 m; and an intra-row spacing of 1 m between individual trees.

Pure maize-legume plots without any trees acted as the control treatments in each block. Different leguminous cover crops (LCC) were integrated seasonally as follows: cowpeas (*Vigna unguiculata*) in LR 2013, Dolichos (*Lablab purpureus*) in SR 2013 and beans (*Phaseolus vulgaris*) in LR 2014. This was to enhance the principle of soil cover. Maize and the leguminous cover crops were harvested at physiological maturity from a net plot of 100 m^2 after leaving 1 m around the plots to avoid the edge effect. The entire plants were harvested by cutting at ground level and weighted to give the total fresh weights. Samples were then taken and the fresh weights were recorded in the field after which they were oven dried in the lab for 48 hours at 65^0 C for moisture content calculation. The maize and bean grain were separated from the cobs and pods by hand shelling and weighed to give net grain weight and the moisture was adjusted to 13% moisture content. Yields were then calculated and extrapolated to Mega grams per hectare basis. The stovers and haulms were completely removed from the conventional agriculture plots and retained on the conservation agriculture plots.

Data collection and Economic Analysis

The actual costs incurred in production were recorded for every season. These costs included the cost of hiring land, the cost of tree seedlings, the cost of seeds and fertilisers, labour charges for land preparation, tree management and harvesting, the cost of herbicides and land preparation costs. These were used to calculate the total variable cost per treatment, which was then compared to the market value of treatment yields (market value of maize and leguminous cover crop yields) through benefit-cost ratio (BCR) to evaluate the feasibility of conservation agriculture with trees to the farmer vis -a -vis conventional practice. The retail market selling price of produce in Machakos was used to calculate the accrued benefits since most farmers in Machakos are small-scale and trade their produce on a retail basis. The key variable costs are presented in *Table 1*, while the retail prices used for cost-benefit analysis are presented in *Table 2*.

Table 1: Key variable costs of production between farming systems in Machakos from SR 2013 to SR 2014

Item	**Actual cost (Ksh. per hectare)**	**USD equivalent (USD 1=Ksh. 100)**
Tree seedlings @ KSH.20 each		
1.5 m by 1 m spacing	162,500	1625
3.0 m by 1 m spacing	90,280	902.8
4.5 m by 1 m spacing	54,160	541.6
Tractor tillage (Conventional farming (COA)	10,000	100
Herbicides (Conservation agriculture (CA)	15,000	150
Harrowing (COA)	7,500	75
Ripping and subsoiling (CA)	11,250	112.5
Planting holes (COA)	5,000	50
Organic manure	4,000	40
Labour (weeding, harvesting, tree coppicing-CA)	48,800	488
Labour (weed scrapping, herbicide application, tree coppicing, planting-CA)	22,940	229.4
Fertiliser (D.A.P)	3,840	38.4
Fertiliser (C.A.N)	3,000	30

Table 2: Market Selling Prices of Produce in Machakos during the study period SR 2013, LR 2013 and SR 2014 as sourced from Machakos retail market

Crop	**Retail price per kilogram (Ksh)**	**USD equivalent (US $1= Ksh. 100)**
Vigna unguiculata (L.) Walp. (cowpeas)	55	0.55
Phaseolus vulgaris L. (beans)	74	0.74
Lablab purpureus L. (dolichos)	100	1
Zea mays L.ssp (Maize)	40	0.4

Statistical Analysis

Analysis of variance (ANOVA) was used to analyse variations in mean benefit-cost ratios, while Fisher's least significant difference (LSD) was used to separate the means at $p <= 0.05$. The statistical tests were conducted with the aid of GENSTAT statistical software version 14. T-tests compared the mean BCR per treatment within the farming systems.

RESULTS AND DISCUSSION

The cost-effectiveness of conservation agriculture and conservation agriculture with trees was determined by valuing the grain yield accrued from both the maize and legume at the market selling price and comparing it with the costs incurred using benefit-cost ratios. Benefit–cost ratios is a ratio that shows the return, in this case, per Kenya shilling invested in farming. *Table 3* shows the benefit-cost ratios per treatment over the three seasons. From Table 3, a general trend is seen where the BCR is higher in all the conservation agriculture treatments compared to the conventional agriculture treatments.

Table 3: Comparison of benefit-cost ratios of conservation agriculture versus conventional agriculture among seasons per treatment in Machakos for the seasons LR 2013, SR 2013 and LR 2014

		Benefit-cost ratios per season		
		LR13	**SR 13**	**LR14**
Treatment*Tillage	Conservation_ Calliandra at 1.5 m	1.9	7.8	8.4
	Conventional_ Calliandra at 1.5 m	1.4	4.9	5.7
	Conservation_ Calliandra at 3 m	2.6	8	7.8
	Conventional_ Calliandra at 3 m	1.9	5.7	5.7
	Conservation_ Calliandra at 4.5 m	3.3	7.7	8.2
	Conventional_ Calliandra at 4.5 m	3.8	6.3	7.3
	Conservation_ Gliricidia at 1.5 m	1.6	7	8.4
	Conventional_ Gliricidia at 1.5 m	1.5	5	6
	Conservation_ Gliricidia at 3 m	2.3	7.4	8.1
	Conventional_ Gliricidia at 3 m	2.2	5.7	5.4
	Conservation_ Gliricidia at 4.5 m	3.3	8.1	7.8
	Conventional_ Gliricidia at 4.5 m	3.5	6.6	5.8
	Conservation_ Pigeon pea at 1.5 m	4.5	6.7	7.9
	Conventional_ Pigeon pea at 1.5 m	5	4.8	6.9
	Conservation_ Pigeon pea at 3 m	3.6	6.5	8
	Conventional_ Pigeon pea at 3 m	5.4	6.2	5.4
	Conservation_ Pigeon pea at 4.5 m	6	8.1	6.2
	Conventional_ Pigeon pea at 4.5 m	5.4	5.3	6.4
	Conservation_ Control	5.6	7.1	9.9
	Conventional_ Control	4.9	5.8	4.7
	P	0.99	0.99	0.99
	LSD	3.7	3.7	3.7
Treatments	Calliandra at 1.5 m	1.7^{b}	6.4^{ab}	7.0^{ab}
	Calliandra at 3 m	2.3^{ab}	6.9^{ab}	6.8^{ab}
	Calliandra at 4.5 m	3.6^{ab}	7.0^{ab}	7.8^{a}
	Gliricidia at 1.5 m	1.5^{b}	6.0^{ab}	7.2^{ab}
	Gliricidia at 3 m	2.3^{ab}	6.6^{ab}	6.7^{ab}
	Gliricidia at 4.5 m	3.4^{ab}	7.3^{ab}	6.8^{ab}

		Benefit-cost ratios per season		
		LR13	SR 13	LR14
	Pigeon pea at 1.5 m	4.8^{ab}	5.8^{ab}	7.4^{ab}
	Pigeon pea at 3 m	4.5^{ab}	6.3^{ab}	6.7^{ab}
	Pigeon pea at 4.5 m	5.7^{ab}	6.7^{ab}	6.3^{ab}
	Control	5.3^{ab}	6.5^{ab}	7.3^{ab}
	p	<0.0.001	<0.0.001	<0.0.001
	LSD	2.02	2.02	2.02
Tillage	Conservation	3.48^{c}	7.45^{a}	8.06^{a}
	Conventional	3.50^{c}	5.64^{b}	5.93^{b}
	LSD	1.47	0.57	0.79
	p	<0.0001	<0.0001	<0.0001

Values with the same superscript letters along a column are not statistically different.

In the first season LR 2013, the net benefits accrued were lowest and this also culminated in the lowest BCR compared to other seasons in all the treatments (1.9 for CA and 1.4 for conventional farming on *Calliandra* at 1.5 m to 5.6 versus 4.9 on control, respectively). The low BCR in this season could be associated with the high initial costs that were incurred at the start of the project, where land had to be opened up by tractor tillage for conventional agriculture and clearance by herbicides for CA, application of organic manure, and also by the high initial costs of tree seedlings which cost Ksh 20 (USD 0.2) each. Planting *Calliandra* at 1.5 m inter-row spacing for instance meant a stand count of 8125 trees per hectare and cost USD 162.5 per hectare (Table 1) without planting labour. Giller *et al*. (2009) illustrate that farmers in Sub-Saharan Africa will always attribute a substantially higher value to initial costs and benefits incurred when practising conservation agriculture than those in the future and that land preparation and weeding are always labour-intensive. This corroborates the high initial costs that were incurred in the study during the first season and it is therefore not unusual. These costs are however a one-time investment and were not in the succeeding seasons; thus, the increase in BCR was noticed in the seasons that followed (from 7.8 in SR13 and 8.4 in LR 14 with *Calliandra* at 1.5 m to 7.1 and 9.9 for conservation agriculture control for the respective seasons).

Even in the practice of sole conservation agriculture (practising the principles of soil cover and minimum tillage without any trees), there was still a high net benefit and high BCR than practising sole conventional farming with tillage and removal of crop residue from the farm without any trees. This is presented in *Table 4* where both the BCR and net benefits are higher in control treatments for conservation agriculture than conventional agriculture in all test seasons but one (BCR = 5.6, 7.1 and 9.9 for CA versus 4.9, 5.8 and 4.7 for conventional agriculture successively). The net benefits in the controls, in this case, were USD 386.26 and 349.03 in LR13, USD 358.13 and 411.83 in SR13 and USD 573.42 and 316.63 in LR14 per hectare for conservation agriculture and conventional practice, respectively.

Table 4: Cost-benefit analysis for different treatments between conventional (COA) and conservation agriculture (CA) in Machakos for seasons LR 2013, SR 2013 and LR 2014

Tillage* treatment	Season	LR 13				SR 13				LR 14			
		Total Costs/ha (USD)	Total Benefits/ha (USD)	Net benefits/ha (USD)	BCR	Total Costs/ha (USD)	Total Benefits/ha (USD)	Net benefits /ha (USD)	BCR	Total Costs/ha (USD)	Total Benefits/ha (USD)	Net benefits /ha (USD)	BCR
conservation agriculture	Calliandra at 1.5 m	2559.4	4776	2216.6	1.9	607.5	4749	4141.5	7.8	692.8	5801	5108.2	8.4
	Calliandra at 3 m	1821.8	4766	2944.2	2.6	607.5	4860.5	4253	8.0	692.8	5429.2	4736.4	7.8
	Calliandra at 4.5 m	1437.8	4800	3362.2	3.3	607.5	4692	4084.5	7.7	692.8	5698.2	5005.4	8.2
	Gliricidia at 1.5 m	2559.4	4144	1584.6	1.6	607.5	4270	3662.5	7.0	692.8	5814.4	5121.6	8.4
	Gliricidia at 3 m	1821.8	4264	2442.2	2.3	607.5	4498	3890.5	7.4	692.8	5577.4	4884.6	8.1
	Gliricidia at 4.5 m	1437.8	4730	3292.2	3.3	607.5	4914.5	4307	8.1	692.8	5435.8	4743	7.8
	Pigeon pea at 1.5 m	846.8	3820	2973.2	4.5	596.1	4009	3412.9	6.7	670	5265.2	4595.2	7.9
	Pigeon pea at 3 m	846.8	3054	2207.2	3.6	596.1	3850.5	3254.4	6.5	670	5333.8	4663.8	8.0
	Pigeon pea at 4.5 m	846.8	5060	4213.2	6.0	596.1	4826	4229.9	8.1	670	4122.8	3452.8	6.2
	Control	835.4	4698	3862.6	5.6	584.7	4166	3581.3	7.1	647.2	6381.4	5734.2	9.9
	Calliandra at 1.5 m	2611.7	3764	1152.3	1.4	872.5	4281	3408.5	4.9	895.3	5076.8	4181.5	5.7
	Calliandra at 3 m	1874.1	3634	1759.9	1.9	872.5	4968.5	4096	5.7	895.3	5089.8	4194.5	5.7
	Calliandra at 4.5 m	1490.1	5600	4109.9	3.8	872.5	5515	4642.5	6.3	895.3	6575.4	5680.1	7.3
	Gliricidia at 1.5 m	2611.7	3832	1220.3	1.5	872.5	4389	3516.5	5.0	895.3	5351	4455.7	6.0
	Gliricidia at 3 m	1874.1	4136	2261.9	2.2	872.5	4991	4118.5	5.7	895.3	4824.8	3929.5	5.4
	Gliricidia at 4.5 m	1490.1	5208	3717.9	3.5	872.5	5743	4870.5	6.6	895.3	5202.4	4307.1	5.8
	Pigeon pea at 1.5 m	899.1	4488	3588.9	5.0	861.1	4128	3266.9	4.8	872.5	6023.2	5150.7	6.9
	Pigeon pea at 3 m	899.1	4894	3994.9	5.4	861.1	5355.5	4494.4	6.2	872.5	4701.2	3828.7	5.4
	Pigeon pea at 4.5 m	899.1	4812	3912.9	5.4	861.1	4549	3687.9	5.3	872.5	5623	4750.5	6.4
	Control	887.7	4378	3490.3	4.9	849.7	4968	4118.3	5.8	849.7	4016	3166.3	4.7
	p	<0.001	0.404	0.901	0.09	<0.001	0.404	0.901	0.09	<0.001	0.404	0.901	0.09
	LSD	957.1	1156	1791	3.7	957.1	1156	1791	3.7	957.1	1156	1791	3.7
Treatments	Calliandra at 1.5 m	2855.6	4270	1684.5	1.7	740	4515	3775	6.4	794.05	5438.9	4644.85	7.0
	Calliandra at 3 m	1847.9	4200	2352.1	2.3	740	4914.5	4174.5	6.9	794.05	5259.5	4465.45	6.8
	Calliandra at 4.5 m	1463.9	5200	3736.1	3.6	740	5103.5	4365.5	7.0	794.05	6136.8	5342.75	7.8
	Gliricidia at 1.5 m	2855.6	3988	1402.5	1.5	740	4329.5	3589.5	6.0	794.05	5582.7	4788.65	7.2
	Gliricidia at 3 m	1847.9	4200	2302.1	2.3	740	4744.5	4004.5	6.6	794.05	5201.1	4407.05	6.7
	Gliricidia at 4.5 m	1463.9	4969	3505.1	3.4	740	5328.8	4588.8	7.3	794.05	5319.1	4525.05	6.8
	Pigeon pea at 1.5 m	872.95	4154	3281.1	4.8	728.6	4068.5	3339.9	5.8	771.25	5644.2	4872.95	7.4
	Pigeon pea at 3 m	872.95	3974	4063.1	4.5	728.6	4603	3874.4	6.3	771.25	5017.5	4646.25	6.7
	Pigeon pea at 4.5 m	872.95	4936	3101.1	5.7	728.6	4687.5	3958.9	6.7	771.25	4827.9	4101.65	6.3

	Season	**LR 13**				**SR 13**				**LR 14**			
Tillage* treatment		**Total Costs/ha (USD)**	**Total Benefits/ha (USD)**	**Net benefits/ha (USD)**	**BCR**	**Total Costs/ha (USD)**	**Total Benefits/ha (USD)**	**Net benefits/ha (USD)**	**BCR**	**Total Costs/ha (USD)**	**Total Benefits/ha (USD)**	**Net benefits/ha (USD)**	**BCR**
	Control	861.55	4538	3676.5	5.3	717.2	4567	3849.8	6.5	748.45	5198.7	4450.25	7.3
	P	<.001	0.929	<.001	<.001	<.001	0.929	<.001	<.001	<.001	0.929	<.001	<.001
	LSD	131.29	1288.5	1285.6	2.02	131.29	1288.5	1285.6	2.02	131.3	1288.5	1285.6	2.02
Tillage	Conservation	1553.69	4411.2	2909.83	3.45	601.8	4483.55	3881.75	7.45	883.9	548.59	4804.52	8.06
	Conventional	1501.38	4474.6	2920.92	3.5	866.89	4888.8	4022	5.64	681.4	524.84	4364.46	5.94
	LSD	640.04	591.85	956.91	1.47	757.38	443.34	441.04	0.57	151.48	609.09	605.95	0.79
	P	<0.0001	<0.0001	<0.0001	<0.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001

DISCUSSION

The generally low BCR in control treatments (except for season LR 2014, where it was 9.9) could be attributed to low accrued benefits, which was also noted by Mucheru-Muna *et al*. (2007) in their study, where they found that control treatments recorded the lowest net benefits of USD 272 per hectare. The high net benefits realised in this study did not however automatically translate to high BCRs as was seen in SR 2013, where control treatments for conservation agriculture had a net benefit of USD 358.13 with a BCR of 7.1 compared to that of conventional farming, which had a BCR of 5.8 with a net benefit of USD 411.83.

Mucheru-Muna (2003) also in her study found that some treatments had high net benefits and low BCR compared to others which had low net benefits with high BCR (*Tithonia diversifolia* with half recommended rate of inorganic fertiliser had a net benefit of Ksh 73,301 with a BCR of 6.8 compared to sole *Tithonia diversifolia* which had 70,253 and 9.6 respectively).

The overall goal of conservation agriculture since the start of its promotion has been to make better use of agricultural resources (than what is done by conventional agriculture) through the integrated management of available soil, water, and biological resources in order for external inputs to be minimised (Garcı´a-Torres *et al*., 2003). It must be socially desirable and potentially attractive to individual farmers (Knowler and Bradshow, 2007). The high BCR found in conservation agriculture treatments are hereby corroborated by the sentiments of the proponents of conservation agriculture, implying high net returns from conservation agriculture with trees, which can thus continue promoting this system as a more attractive agricultural practice.

In both developing and developed world, research through numerous financial analyses has indeed revealed that conservation agriculture generally leads to relatively higher returns as compared to conventional practice since the 1980s (Sorrenson *et al*., 1998; Stonehouse, 1997), and this has been attributed to the relatively low cost of the machinery (although special and might not be readily available) coupled with improved yields, savings in time and similar savings in labour (Knowler and Bradshow, 2007). In Sub-Saharan Africa, out of 11 financial analyses on conservation agriculture, 10 emerged with high net profit, while in Latin America and the Caribbean, 16 of 18 financial analyses showed high net profits through the practice of the principles of conservation agriculture (Knowler, 2003). This is a positive analogy to the high benefit-cost ratios in this study and affirms the efficacy of the system in cost savings and beneficial gains. Knowler (2003) also recorded that 33 out of 59 analyses Sub Saharan Africa have also revealed high profits through the integration of trees into farming systems (agroforestry) and this could therefore have caused an additional effect on the returns from conventional agriculture; thus, the high BCRs that were recorded in this study in conservation agriculture with tree treatments.

The total benefits exceeded the total costs from the study and this is corroborated by the argument of Triplett and Dick (2008) that even though the costs of production for both conservation and conventional tillage might at times be equal, the yields of the two systems always drive profitability with conservation agriculture generally recording high return to land, labour, and management.

CONCLUSION

The findings of this study have given an implication that tree-based conservation agriculture systems (CAWT) will surely be the solution that the dryland agroecosystems need to bounce back and improve livelihoods. The efficacy of these systems coupled with their external net benefits is no more in doubt, and if they can bring higher net profits than conventional practice as has been affirmed, then it means more attractiveness to the farmers (which they actually look at) and as such, more efforts should be made to enhance their promotion. Practising conservation farming either as a sole or with the integration of tree component have been seen to be beneficial in terms of high benefit-cost ratios and higher net benefits compared to conventional farming, although the costs will be higher at the initial stages. The integration of trees into cropping systems can thus be said to be a viable practice that indeed, results in yield improvement. A farmer can therefore have a one-time investment in conservation agriculture with trees and be able to reap in the succeeding seasons.

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