Africa RISING – Sustainable Intensification and Diversification of Maize-based Farming Systems in Malawi

Final Report

Reporting Period: 1 April 2012 – 31 March 2013

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Project Objectives:

Analyze the impact of three agricultural production systems--conservation agriculture (CA), continuous no-till (NT) maize, and conventional tillage (CV)--on the following:

-Food production
-Soil fertility and quality
-Human nutrition
-Resilience to drought and climate variability and change
-Household income

Partners:

CIMMYT: Dr. Christian Thierfelder, Conservation Agriculture, CIMMYT, Harare, Zimbabwe; Dr. Bruno Gérard, Director Global Conservation Agriculture Program, CIMMYT, Addis Ababa, Ethiopia

Dr. Thierfelder will serve as the lead partner and PI on this project and be responsible for reporting and financial management. Drs. Thierfelder and Gérard will offer logistical support and expertise and assist in disseminating project outcomes in East and Southern Africa.

Washington State University: Dr. John P. Reganold, Agroecologist, Department of Crop and Soil Sciences, WSU, Pullman, WA; Daniel TerAvest, PhD candidate, Department of Crop and Soil Science, WSU, Lilongwe, Malawi; Dr. Philip Wandschneider, Agricultural Economist, School of Economic Sciences, WSU, Pullman, WA

The project manager, Dan TerAvest, lives in Malawi and is a Ph.D. candidate at WSU. His advisor, Dr. John Reganold, is the project Co-PI and his job includes management support, higher education policy analysis and support, university administration and planning assistance, and assistance to Dan TerAvest in implementing the program. Dr. Wandschneider will assist with economic analysis of the agricultural production systems.

Total LandCare: Dr. Trent Bunderson, Executive Director, TLC, Lilongwe, Malawi; Zwide Jere, Managing Director, TLC, Lilongwe, Malawi

Total LandCare will offer on-the-ground logistical support, assist with project activities, and help disseminate project outcomes to smallholder farmers in the region.

Bunda College of Agriculture: Dr. Patson Nalivata, Soil Scientist, Bunda College of Agriculture, Lilongwe

Bunda College of Agriculture will conduct the laboratory analyses and will also offer local expertise and assist in the dissemination of project outcomes.

Achievements against plan: Africa RISING funding assisted in completing the 1st year of a 3-year research project with the objectives listed above. Below is a summary of the data collection, sample analysis, and results from the 1st year of research that go towards achieving this project's objectives:

I. **Food Production:** Sweet potato and cassava leaves were harvested for green vegetables during the growing season. Leaf harvests per households were recorded and samples of sweet potato and cassava leaves collected. In May 2012, no-till maize plots in Dowa and Nkhotakota districts and sweet potatoes in CA and CV plots were harvested. Yield data were recorded and maize and sweet potato samples were collected. Cassava in CA and CV plots in Nkhotakota was harvested in November 2012. Yield data are presented in Table 2.

Sweet potato and cassava yields were lower in CA compared to CV plots. However, 2 of the 3 participating farmers thought that sweet potato quality was better in the CA plots and would be interested in growing CA sweet potato again if yields could be increased. Therefore, more research needs to be done to develop strategies to successfully increase sweet potato yields in CA systems. After seeing the results from their CA and CV cassava, participating farmers in Nkhotakota were not interested in incorporating cassava into CA systems. Maize yields of 3.7 and 4.2 tons ha^{-1} in Dowa and Nkhotakota NT plots, respectively, were much greater than average maize yields in Malawi (2-2.5 tons ha^{-1}), suggesting that NT can increase maize productivity on smallholder farms. However, it is not clear whether fertilizer usage or land management was responsible for the yield increases. We will examine this issue more closely in year 3, when all plots will be planted to maize.

II. **Soil Fertility and Quality:** Soil samples were collected in December 2011 at 5 depths: 0-10 cm, 10-20 cm, 20-30 cm, 30-60 cm, and 60-90 cm. Bulk density soil samples (0-10 cm and 10-20 cm) were collected in June 2012. Soil samples were analyzed for soil physical and chemical parameters. Soil physical properties included soil texture and bulk density (Table 3). Soil chemical properties included pH and exchangeable acidity (Table 4) as well as organic C, inorganic N (NO_3^- + NH_4^+), available P, K, Ca, Mg, and Zn (Table 5). Crop residue production and quality (residue C, N, and P) for each crop and treatment were analyzed and the data are reported in Table 6.

Although there are no noticeable differences in soil fertility and quality between NT, CA and CV plots at this time, it often takes 3-5 years for soil fertility and quality to change noticeably after adoption of new land management practices. This project began two years after participating farmers adopted no-till maize production. Soil fertility and quality data presented here are after 2 years of no-till management (in the NT and CA plots), but prior to establishment of crop rotations.

III. **Human Nutrition:** Yield data for all crops grown was combined with the nutritional output data from the USDA National Nutrient Database (http://www.ars.usda.gov/Services/docs.htm?docid=8964). Total nutritional output per hectare for each treatment in Dowa and Nkhotakota districts are presented in Tables 7 and 8.

Although CA cassava and sweet potato yields were lower than normal for the district, per hectare outputs of certain vitamins and minerals, such as Ca, K, and vitamin C, were greater in the CA and CV plots compared to no-till maize plots. Therefore, sweet potato and cassava could be important rotation crops for improving household nutrition. Intercropping pigeon pea also increases the availability of nutritious foods at the household level; however, low pigeon pea yields reduced its nutritional advantages as an intercrop. Low pigeon pea yields were due in part to low planting density when planted as an intercrop, pest damage, and a late planting date in Dowa.

IV. **Resilience to drought and climate variability and change:** Continuous logging soil moisture sensors were installed at 20 cm, 40 cm, 60 cm, and 80 cm depths in the CA and conventional rotation plots before planting. Soil moisture sensors recorded soil moisture (and soil temperature at 20 cm) every 4 hours. Soil moisture and temperature data were downloaded monthly. In Dowa, final soil moisture and temperature data collection and removal of sensors were completed at sweet potato harvest. Soil moisture sensor data in Nkhotakota district are presented through August 25, 2012. Soil moisture and temperature data are presented in Figures 1 and 2. Failure of some soil moisture sensors during the growing season resulted in gaps in soil moisture data in figures 1 and 2. The manufacturer acknowledged their responsibility for this problem and replaced all failed sensors before the 2012-2013 growing season.

In Nkhotakota, participating farmers had practiced residue management as part of CA for 2 years prior to the 2011-12 growing season. In Dowa, farmers had not yet started retaining residues on the field in the 2011-12 growing season. In Nkhotakota, with residues, CA sites had higher moisture content than CV sites at 20 and 40 cm depths throughout the growing season. At 60 and 80 cm depths, soil moisture content was similar between CA and CV early in the year, but was greater in CA later in the growing season. In Dowa, without residues, soil moisture content at 20 cm was greater in CA than CV. However, at 40 and 60 cm depths, CV plots had greater soil moisture than CA plots. This suggests that rainwater infiltration and retention in CA plots with residue retention is greater than for conventional ridging. Conversely, in the absence of residues, rainwater infiltration and retention is greater in CV plots. Additionally, the presence of residues in Nkhotakota reduced soil temperatures in CA relative to CV plots, whereas soil temperatures were similar in CV and CA plots without residues in Dowa.

V. **Household Income:** Partial budget analysis was used to determine the benefit/cost ratio of each agricultural production system. Input prices--seed, fertilizer, and herbicides--were priced based on retail prices at trading centers and towns near research sites at the time of planting. Labor costs were determined using both opportunity cost and daily wages. Opportunity costs for labor were determined by interviewing farmers about cost of hiring out labor operations instead of using household labor. A daily wage equal to Malawi's minimum daily wage was also used to calculate labor costs. Output prices were based on sale prices of each crop in the village at the time of, or shortly after, harvest. Detailed economic analysis of NT plots in Dowa and Nkhotakota, CA and CV plots in Dowa, and CA and CV rotation plots in Nkhotakota district are presented in Tables 9, 10, and 11, respectively. For year 1, we reported only a basic partial budget analysis. After completion of the 3-year project, we hope to do a more complete economic analysis, including sensitivity analysis as well as accounting for environmental costs and benefits of all three agricultural production systems.

The benefit/cost ratios of all 6 treatment/district combinations were dependant on the methods used to calculate labor costs. The Nkhotakota research sites are located near Lake Malawi, near a main road, and near a town. The result was that the opportunity costs of labor are higher than when a daily minimum labor wage is used. The Dowa sites are located in a rural village, far from any major town or road or Lake Malawi, and therefore opportunity costs of labor were close to the minimum daily labor wage. Using the benefit/cost ratio (using the daily minimum wage method), the benefit/cost ratios of conventionally produced cassava and sweet potato are close to or greater than the benefit/cost ratio of no-till maize. Therefore, these alternative crops can be as beneficial to smallholder farmers as maize, and may be viable options to diversify maize-based agricultural production systems in Malawi.

Key Deliverable Deviation: The laboratory manager of the human nutrition laboratory at Bunda College of Agriculture (now part of the Lilongwe University of Agriculture and Natural Resources) resigned his position and was not replaced by the time the Africa RISING project was finished. Therefore, we were not able to conduct laboratory analyses of nutritional output for each crop grown; instead, we used the USDA National Nutrient Database for crops to estimate total nutrient output by crop and treatment.

List of geo-tagged sites where activities took place:

Table 1. Geo-tagged locations of all 8 on-farm research trials.

Farmer Surname	Latitude	Longitude	Elevation
Nkhotakota District			
Washali	S 13°07'22.5"	E 034°19'23.9"	452 m
Kagona	S 13°05'25.3"	E 034°18'26.1"	497 m
Ngombe	S 13°04'51.3"	E 034°18'13.1"	519 m
Gumbwa	S 12°57'07.3"	E 034°15'58.9"	525 m
Dowa District			
Kakusa	S 13°20'19.6"	E 033°41'39.1"	1171 m
Phiri	S 13°19'32.0"	E 033°43'06.4"	1131 m
Tengani (1)	S 13°19'33.1"	E 033°42'26.7"	1159 m
Tengani (2)	S 13° 19'28.5"	E 033° 43'03.8"	1124 m

Support of Africa RISING: Support from Africa RISING was crucial in sustaining this project by funding the first growing season of at least three growing seasons needed to complete the rotation cycle of the three agricultural production systems being studied. The outputs from this research project benefit the long-term goals of Africa RISING by evaluating demand-driven options for sustainable intensification that contribute to rural poverty alleviation, improved nutrition and equity, and ecosystem stability. Additionally, strong collaboration between CIMMYT, Washington State University, Total LandCare, and Bunda College of Agriculture will facilitate partner-led dissemination of integrated innovations for sustainable intensification beyond the Africa RISING action research.

Lessons learnt: The primary objective of this project is to assist TLC in developing practical agricultural production systems that increase food production, improve nutrition, enhance soil fertility, improve climate resilience, and improve household income. In this 1st year of research we were able to help TLC in achieving that goal. First of all, the performance of cassava under CA and CV suggests that, while cassava can offer nutritional and economic benefits to farmers in conventional systems, cassava should not be promoted in CA systems. On the other hand, while CA sweet potato also yielded less than CV sweet potatoes, improved nutritional outputs combined with farmers perceptions that CA sweet potatoes were of better quality indicates that farmers would be interested in adopting CA sweet potato if the yield-limiting factors in CA sweet potato were to be identified and addressed. Soil moisture data from Nkhotakota and Dowa reinforce the perception that residue management is a critical aspect of CA, without which the resilience to climate variability and drought is reduced.

The data generated here will help TLC make informed decisions about which types of practical agricultural production systems to promote. For example, cassava can be promoted as an income- and nutrition-enhancing crop, but should not be promoted in CA systems. Likewise, sweet potatoes should not be promoted in CA systems until yields can be improved. Promoting CA can help build resilience to climate variability and drought, but only if crop residues are retained as a surface mulch.

Publicity: This study forms the basis for D. TerAvest's PhD study at Washington State University. As such, it is expected that D. TerAvest will publish at least 3 peer-reviewed journal articles upon completion of this research project in 2014.

USAID indicators:

Indicator #11: Members of 2 producer organizations were trained in new land management practices
Indicator #27: Seven farmers (5 male and 2 female) were trained in new land management practices
Indicator #39: Two new management practices were under research and 1 technology was under field testing

Custom indicators:

Increasing the capacity of the soil quality laboratory at Bunda College of Agriculture:

The laboratory capacity of the soil quality laboratory at Bunda College of Agriculture was increased, where all project soil and plant residue samples were analyzed. First, purchase of additional glassware, a balance, a hotplate, and pipettes have increased the number of samples that the laboratory can analyze per day. For example, prior to purchasing these supplies, the laboratory could analyze a maximum of 6 soil or plant samples per day for total N; now they are able to analyze 81 samples per day, a 1,350% increase. Additionally, the laboratory technicians have learned new skills and more efficient methods of analysis. As mentioned above, we were unable to work with, or build capacity in, the human nutrition laboratory.

Increase access to more nutritious food to 39 children in Malawi:

Thirty-nine children had access to more nutritious food, including sweet potato and pigeon pea, because of this project. Twelve children in Dowa had improved access to sweet potato, and five of these children also had improved access to pigeon pea. In Nkhotakota, 27 children had access to pigeon pea. These foods can be an important source of nutrition because they can improve children's intake of protein (pigeon pea) and Ca, K, and vitamin C (sweet potato).

Table 2. Crop yields by treatment and district

District	Treatment	Crop	Yield
Dowa	No-till	Maize	3,1 kg ha^{-1}
	Conservation Agriculture	Sweet potato	6,864 kg ha^{-1}
		Sweet potato leaves	44 kg ha^{-1}
		Pigeon pea	25 kg ha^{-1}
	Conventional Rotation	Sweet potato	9,131 kg ha^{-1}
		Sweet potato leaves	44 kg ha^{-1}
Nkhotakota	No-till	Maize	4,174 kg ha^{-1}
	Conservation Agriculture	Cassava	2,624 kg ha^{-1}
		Cassava leaves	88 kg ha^{-1}
		Pigeon pea	81 kg ha^{-1}
	Conventional Rotation	Cassava	6,005 kg ha^{-1}
		Cassava leaves	88 kg ha^{-1}

Table 3. Soil physical properties by district, soil depth, and treatment

	Nkhotakota	Dowa

Depth (cm)	Soil texture (%) Sand	Silt	Clay	Sand	Silt	Clay
0-10	89	3	8	81	4	15
10-20	89	3	8	79	4	17
20-30	77	2	21	67	2	32
30-60	69	5	26	60	6	34
60-90	68	4	29	59	6	35
	Bulk Density ($Mg\ m^{-3}$)					
	NT[z]	CA	CV	NT	CA	CV
0-10	1.42	1.44	1.40	1.35a[y]	1.35a	1.28b
10-20	1.37	1.43	1.42	1.40	1.43	1.33

[z]NT = no-till maize; CA = conservation agriculture; and CV = conventional rotation

[y]Values within a row followed by the same letter are not significantly different ($P \le 0.05$)

Table 4. Soil pH and exchangeable acidity by district, treatment, and soil depth

		Nkhotakota			Dowa		
Parameter	Depth (cm)	NT[z]	CA	CV	NT	CA	CV
pH ($CaCl_2$)	0-10	4.6	4.6	4.6	5.2	5.0	5.0
	10-20	4.4	4.1	4.4	5.3	4.8	4.7
	20-30	4.5	4.3	4.2	4.9	5.1	4.6
	30-60	4.7	4.5	4.4	5.1	4.9	5.0
	60-90	4.7	4.7	4.6	5.5	5.5	5.3
Exchangeable	0-10	1.6	1.9	2.5	1.5	1.8	1.3
Acidity	10-20	4.0	5.3	4.4	1.3	1.5	2.0
cmol kg^{-1}	20-30	3.9	7.1	6.7	1.8	1.5	1.3
	30-60	3.1	6.0	6.1	1.3	1.5	1.3
	60-90	4.3	4.4	4.5	1.5	1.3	1.5

[z]NT = no-till maize; CA = conservation agriculture; and CV = conventional practice

Table 5. Soil chemical properties by district, treatment, and soil depth

Parameter	Depth (cm)	Nkhotakota			Dowa		
		NT[z]	CA	CV	NT	CA	CV
Organic C	0-10	11.2	9.3	7.7	15.4	16.1	17.1
g kg^{-1}	10-20	8.5	8.0	9.6	12.3	13.8	14.2
	20-30	5.5	9.2	3.2	11.3	12.4	11.4
Inorganic N	0-10	41	35	41	187a[y]	121ab	74b
mg kg^{-1}	10-20	34	28	28	101	113	84
	20-30	26	28	25	98	95	92
	30-60	23	22	25	64	67	91
	60-90	19	21	24	58	61	60
Available P	0-10	72	80	95	31	71	41
mg kg^{-1}	10-20	61	59	82	21	36	26
	20-30	58	50	72	10	23	9
	30-60	44	38	55	2	5	5
	60-90	35	29	40	0.2	0.3	0.0
K	0-10	0.43	0.51	0.30	0.67	0.68	0.67
cmol kg^{-1}	10-20	0.36	0.31	0.20	0.46	0.52	0.58
	20-30	0.28	0.32	0.21	0.38	0.43	0.36
	30-60	0.27	0.26	0.33	0.23	0.19	0.23
	60-90	0.22	0.20	0.27	0.30	0.30	0.33
Ca	0-10	34	37	43	21	23	20
cmol kg^{-1}	10-20	33	33	35	22	20	19
	20-30	33	32	34	19	18	17
	30-60	37	41	34	19	18	16
	60-90	39	44	39	18	17	14
Mg	0-10	4.9	3.9	3.7	5.6	5.8	5.9
cmol kg^{-1}	10-20	4.8	3.8	3.0	6.0	5.5	5.5
	20-30	5.5	4.2	3.5	6.3	6.0	5.6
	30-60	6.8	5.3	4.0	7.1	5.9	6.2
	60-90	7.4	5.7	4.7	7.4	6.6	6.4
Zn	0-10	5.2	4.0	4.1	28.2	31.5	28.3
mg kg^{-1}	10-20	5.3	2.9	4.4	28.8	18.0	17.1
	20-30	4.5	3.5	2.4	14.9	10.2	17.0
	30-60	3.7	3.3	4.0	20.2	12.3	11.8
	60-90	3.6	2.8	3.8	11.1	10.8	10.9

[z]NT = no-till maize; CA = conservation agriculture; and CV = conventional practice
[y]Values within a row followed by the same letter are not significantly different (P ≤ 0.05)

Table 6. Residue production, residue quality, and total nutrients returned to the soil in residues by crop and treatment.

Treatment	Crop	Residue	C output		N output		C:N	P output	
		Tons ha^{-1}	C %	Kg C ha^{-1}	N %	Kg N ha^{-1}		P %	Kg P ha^{-1}
<u>Nkhotakota</u>									
No-till	Maize	4.92	44.2	2,214	0.36	17.2	129	0.09	4.3
Conservation Agriculture	Cassava	0.31	35.4	109	1.38	4.2	26	0.17	0.5
	Pigeon Pea	0.40	50.8	205	1.12	4.7	50	0.11	0.5
	Total	0.71		314		8.9			1.0
Conventional Practices	Cassava	0.58	36.0	210	1.04	6.1	35	0.17	1.0
<u>Dowa</u>									
No-till	Maize	4.39	42.7	1,878	0.38	16.7	118	0.06	2.6
Conservation Agriculture	Sweet Potato	1.60	39.6	634	1.55	25.4	27	0.18	2.8
	Pigeon Pea	0.15	30.2	46	0.37	0.6	101	0.10	0.2
	Total	1.75		681		26.0			3.0
Conventional Practice	Sweet Potato	1.41	37.5	528	2.41	34.0	16	0.18	2.58

Table 7. Total nutrient output per hectare by treatment in Dowa District.

Nutrient	Unit ha^{-1}	No-Till Maize Maize	Conservation Ag. Sweet potato Sweet potato leaves Pigeon Pea	Conventional Rotation Sweet potato Sweet potato leaves
Energy	Mj	46,160[z]	28,530	37,419
Protein	Kg	285	130	164
Total lipid	Kg	143	4	5
Carbohydrate	Kg	2,243	1,589	2,090
Fibre, total dietary	Kg	221	239	312
Sugars, total	Kg	19	326	434
Minerals				
Calcium	G	211	2,389	3,127
Iron	G	82	49	64
Magnesium	G	3,836	2,022	2,617
Phosphorus	g	6,343	3,801	4,912
Potassium	g	8,669	26,858	35,165
Sodium	g	1,057	4,298	5,711
Zinc	g	67	24	31
Vitamins				
Vitamin C	g	0	191	253
Thiamin	g	12	6	8
Riboflavin	g	6	5	6
Niacin	g	110	45	58
Vitamin B-6	g	19	16	22
Folate	g	1	1	1
Vitamin A	g	0	55	74

[z]USDA National Nutrient Database (http://www.ars.usda.gov/Services/docs.htm?docid=8964)

Table 8. Total nutrient output per hectare by treatment in Nkhotakota District.

Nutrient	Unit ha^{-1}	No-Till Maize Maize	Conservation Ag. Cassava Cassava leaves Pigeon Pea	Conventional Rotation Cassava Cassava leaves
Energy	Mj	52,435[z]	18,780	40,227
Protein	Kg	323	64	90
Total lipid	Kg	163	9	17
Carbohydrate	Kg	2,548	1,059	2,295
Fibre, total dietary	Kg	250	62	109
Sugars, total	Kg	22	44	102
Minerals				
Calcium	G	240	538	961
Iron	G	93	15	19
Magnesium	G	4,358	717	1,261
Phosphorus	g	7,206	1,044	1,621
Potassium	g	9,848	8,352	16,274
Sodium	g	1,201	380	841
Zinc	g	76	12	21
Vitamins				
Vitamin C	g	0	614	1,310
Thiamin	g	13	3	5
Riboflavin	g	7	1	3
Niacin	g	124	25	51
Vitamin B-6	g	21	3	5
Folate	g	1	1	2
Vitamin A	g	0	0	0

[z]USDA National Nutrient Database (http://www.ars.usda.gov/Services/docs.htm?docid=8964)

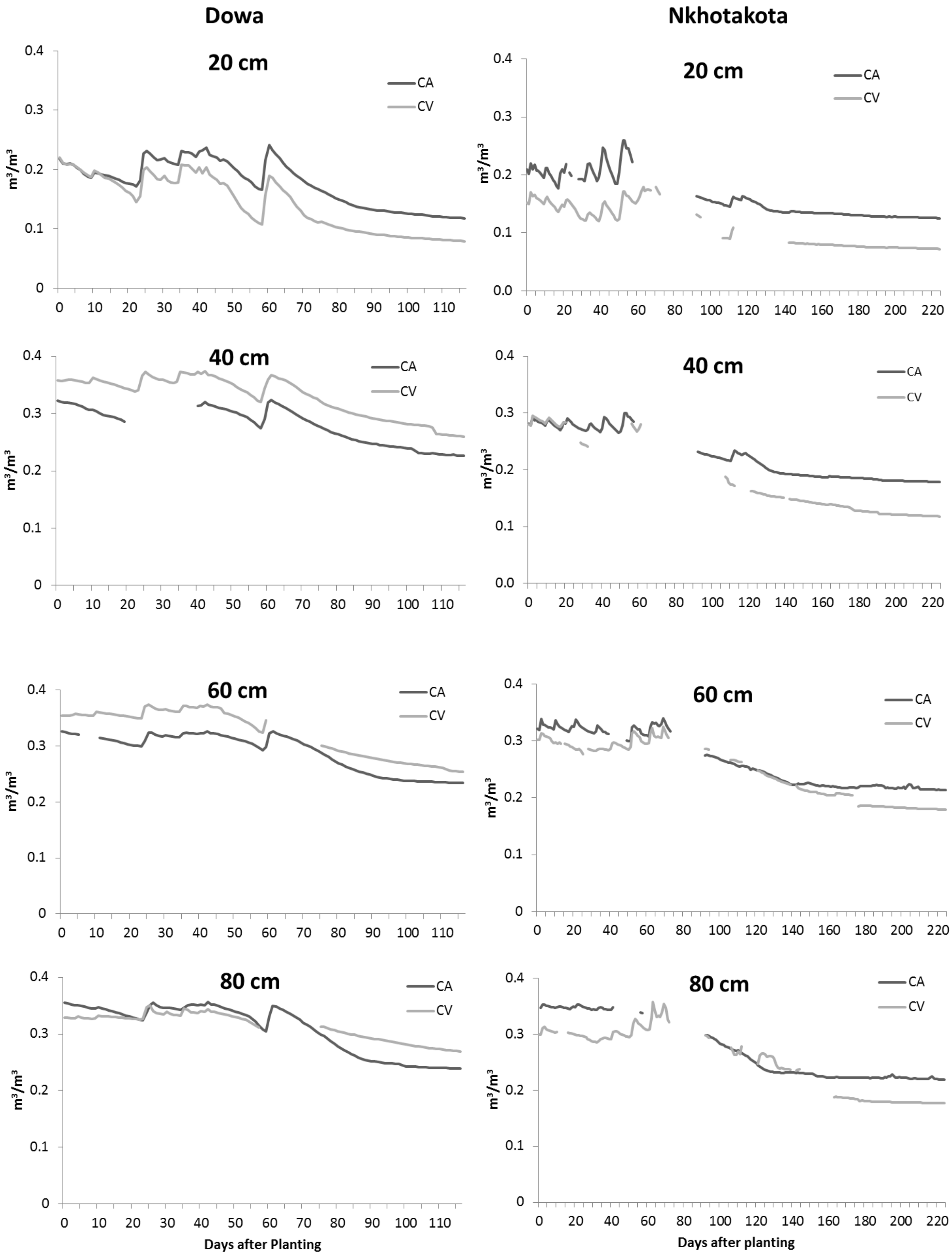
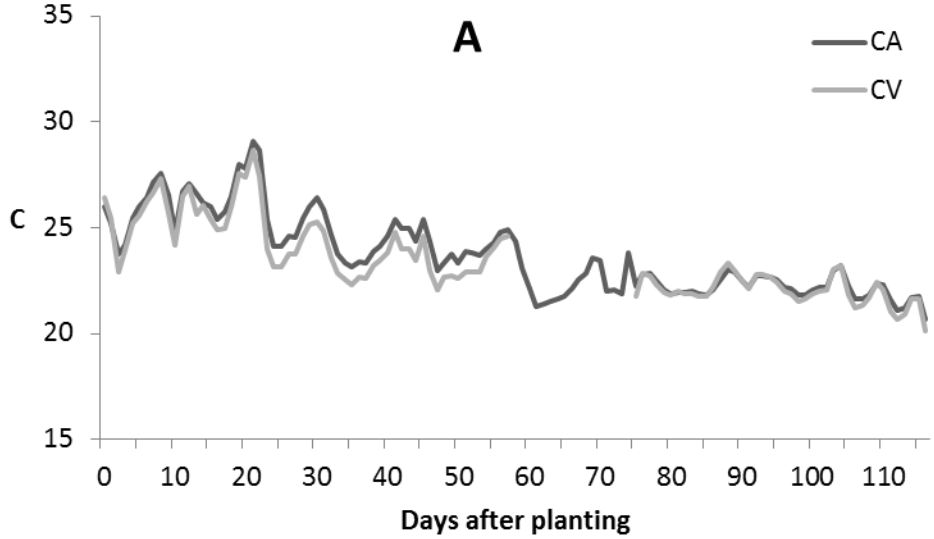


Figure 1. Soil moisture content at 20 cm, 40 cm, 60 cm, and 80 cm in Dowa (left) and Nkhotakota (right) for conservation agriculture (CA) and conventional rotation (CV). Conservation agriculture plots in Dowa did not have crop residue cover.



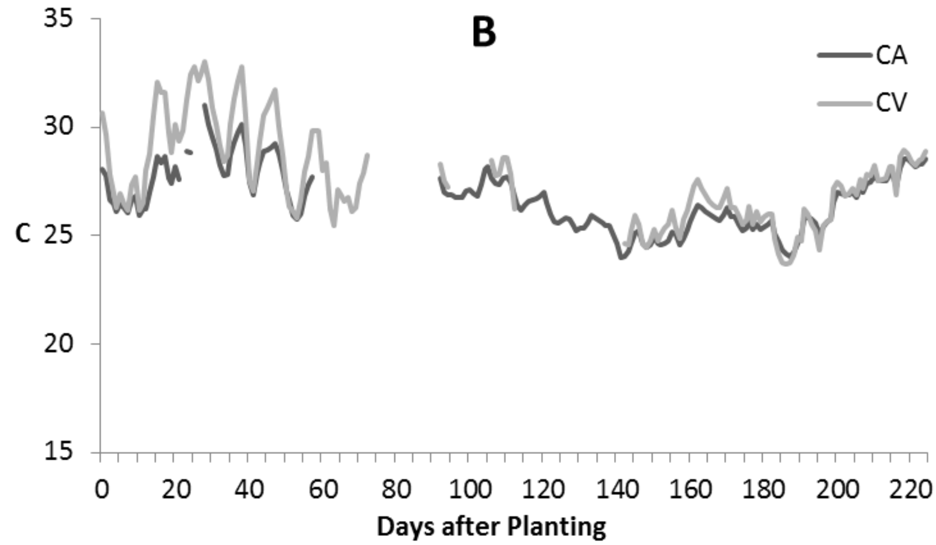


Figure 2. Soil temperature at 20 cm in A) Dowa and B) Nkhotakota for conservation agriculture (CA) and conventional rotation (CV). Conservation agriculture plots in Dowa did not have crop residue cover.

Table 9. Partial Budget analysis for the No-till maize plots in Nkhotakota and Dowa Districts. Labour costs were calculated using 2 methods--the daily labour wage and opportunity cost.

		NKHOTAKOTA				DOWA			
	Unit	**US$/unit**	**Quantity**	**Total US$**	**Total US$**	**US$/unit**	**Quantity**	**Total US$**	**Total US$**
REVENUE									
Maize	Kg	**0.23**	**4,136**	**961.92**		**0.21**	**3,641**	**762.12**	
VARIABLE COSTS									
Inputs (US$)									
Maize Seed	5 kg bag	10.47	5	52.33		9.30	5	46.51	
23:21:0:4	50 kg bag	40.35	3	121.05		39.16	3	117.47	
UREA	50 kg bag	43.26	3	129.77		37.53	3	112.59	
Roundup	L	13.49	2.5	33.73		13.49	2.5	33.73	
Bullet	L	12.09	1	12.09		12.09	1	12.09	
Total Input Costs				**348.97**				**322.39**	
Labour Costs		**(8 hr day)**	**Daily Labour**		**Opportunity Cost**	**(8 hr day)**	**Daily Labour**		**Opportunity Cost**
Laying out Residue	Day	1.16	6.8	7.91	28.46	1.16	0	0	0
Planting Maize	Day	1.16	34.3	40.04	142.30	1.16	21.7	25.27	34.81
Fertilizer Application (2x)	Day	1.16	20.1	23.07	199.37	1.16	17.5	20.35	69.62
Weeding (2x)	Day	1.16	58.2	69.57	289.04	1.16	62.9	73.08	72.35
Herbicide Application (2x)	Day	1.16	1.6	2.45	57.11	1.16	1.5	1.71	35.92
Harvesting	Day	1.16	20.7	22.99	120.09	1.16	17.7	20.58	88.21
Total Labour Costs	Days		**142.8**	**166.03**	**836.38**		**121.3**	**141.00**	**300.91**
Sprayer Costs									
Depreciation (Total days use)		100 Days	50	1.6	1.05		1.5	0.73	
Maintenance (half depreciation)		100 Days	50	0.8	0.53		0.75	0.37	
Total Sprayer Costs					**1.58**		**-**	**1.10**	
Total Transportation Costs				**8.39**	**8.39**			**10.89**	**10.89**
Total Variable Costs				**524.96**	**1183.83**			**475.38**	**635.30**
Net Returns				**436.96**	**-221.91**			**286.74**	**126.83**

Benefit/Cost Ratio	**1.83**	**0.81**	**1.60**	**1.20**

Table 10. Partial budget analysis for conservation agriculture and conventional rotation plots in Dowa district. Labour costs were calculated using 2 methods--daily labour wage and opportunity cost.

			Conservation Agriculture			Conventional Rotation		
	Unit	**US$/unit**	**Quantity**	**Total US$**	**Total US$**	**Quantity**	**Total US$**	**Total US$**
REVENUE								
Sweet Potato	Kg	0.08	6864	574.66		9131	764.41	
Sweet Potato Leaves	400 g	0.14	94	13.06		94	13.06	
Pigeon Pea	Kg	1.40	27	37.52		-	-	
Vine Transplants	Bundles	2.33	39	90.54		39	90.54	
TOTAL REVENUE				**715.78**			**868.01**	
VARIABLE COSTS								
Inputs								
Sweet Potato Vine	Bundle	2.33	154	358.14		154	358.14	
Pigeon Pea Seed	Kg	1.98	3.5	6.92		-	-	
Fertilizer (23:21:0:4)	50kg bag	39.16	2	78.32		2	78.32	
Roundup	L	13.49	2.5	33.72		-	-	
Total Input Costs				**477.10**			**436.46**	
Labour Costs		**(8 hr day)**	**Daily Labour**		**Opportunity Cost**	**Daily Labour**		**Opportunity Cost**
Tilling Ridges	Day	1.16	-	-	-	35.4	41.12	45.86
Planting Sweet Potato	Day	1.16	20.0	23.26	35.08	15.5	18.07	35.08
Planting Pigeon Pea	Day	1.16	3.2	3.76	21.89	-	-	-
Fertilizer Application	Day	1.16	5.4	6.22	35.08	5.1	5.97	35.08
Weeding (2x)	Day	1.16	86.33	100.39	83.37	72.4	84.18	62.49
Herbicide Application	Day	1.16	1.03	1.20	27.83	-	-	-
Harvesting Sweet Potato	Day	1.16	18.2	21.11	110.45	14.5	16.88	97.74
Harvesting Pigeon Pea	Day	1.16	1.2	1.43	10.54	-	-	-
Total Labour Costs	Days		**135.3**	**157.35**	**324.23**	**142.9**	**166.21**	**276.25**
Sprayer Costs								
Depreciation (Total days use)		100 Days	50	1.03	0.51		-	-
Maintenance (half depreciation)		100 Days	50	0.52	0.26		-	-
Total Sprayer Costs					**0.77**		**-**	-

Transportation Costs	**9.45**	**9.45**	**9.45**	**9.45**
Total Variable Costs	**644.67**	**811.55**	**612.13**	**722.61**
Gross Margins	**71.11**	**-95.77**	**255.89**	**145.40**
Benefit/Cost Ratio	**1.11**	**0.88**	**1.42**	**1.20**

Table 11.Partial budget analysis for conservation agriculture and conventional practices plots in Nkhotakota district. Labor costs were calculated using a daily labor wage and opportunity cost.

			Conservation Agriculture			Conventional Practice		
	Unit	**US$/unit**	**Quantity**	**Total US$**	**Total US$**	**Quantity**	**Total US$**	**Total US$**
REVENUE								
Cassava	Kg	0.12	2604	302.78		6005	698.27	
Cassava Leaves	400 g	0.21	234	50.15		221	47.20	
Pigeon Pea	Kg	1.44	93	129.77		-	-	
Stem Transplants	Bundles	2.33	108	250.33		108	250.33	
Firewood	Kg	0.07	377	26.28		351	24.49	
TOTAL REVENUE				**759.30**			**1020.29**	
VARIABLE COSTS								
Inputs								
Cassava cuttings	Bundle	2.33	70	162.79		70	162.79	
Pigeon Pea Seed	Kg	1.98	4	7.91		-	-	
Fertilizer (23:21:0:4)	50 kg	40.35	2	80.70		2	80.70	
Roundup	L	13.49	2.5	33.72		-	-	
Total Input Costs				**285.12**			**243.49**	
Labour Costs		**(8 hr day)**	**Daily Labor Method**		**Opportunity Cost**	**Daily Labor Method**		**Opportunity Cost**
Tilling Ridges	Day	1.75	-	-	-	35.4	41.19	163.99
Residue Management	Day	1.75	6.4	7.40	28.00	-	-	-
Planting Cassava	Day	1.75	19.3	22.47	130.09	11.4	13.25	89.14
Planting Pigeon Pea	Day	1.75	8.5	9.92	80.57	-	-	-
Fertilizer Application	Day	1.75	4.41	5.13	86.18	2.7	3.11	101.09
Weeding (2x)	Day	1.75	53.4	62.05	291.03	61.9	71.93	291.82
Herbicide Application	Day	1.75	0.9	1.07	28.25	-	-	-
Harvesting Cassava	Day	1.75	16.9	19.68	208.89	12.2	14.16	97.50
Harvesting Pigeon Pea	Day	1.75	10.2	11.91	89.18	-	-	-
Total Labour Costs	Days		**120.1**	**139.62**	**942.18**	**123.5**	**143.64**	**743.53**
Sprayer Costs								
Depreciation (Total days use)	100 Days	50	0.9	0.46		-	-	-

Maintenance (half depreciation)	100 Days	50	0.45	0.23		-	-	-
Total Sprayer Costs				**0.69**	**0.69**		**-**	-
Transportation Costs				**3.38**	**3.38**		**3.38**	**3.38**
Total Variable Costs				**428.80**	**1231.37**		**390.51**	**990.40**
Gross Margins				**330.50**	**-472.06**		**629.78**	**29.90**
Benefit/Cost Ratio				**1.77**	**0.62**		**2.61**	**1.03**