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

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The Africa Research In Sustainable Intensification for the Next Generation (Africa RISING) program comprises three research-for-development projects supported by the United States Agency for International Development as part of the U.S. government's Feed the Future initiative.

Through action research and development partnerships, Africa RISING will create opportunities for smallholder farm households to move out of hunger and poverty through sustainably intensified farming systems that improve food, nutrition, and income security, particularly for women and children, and conserve or enhance the natural resource base.

The three projects are led by the International Institute of Tropical Agriculture (in West Africa and East and Southern Africa) and the International Livestock Research Institute (in the Ethiopian Highlands). The International Food Policy Research Institute leads an associated project on monitoring, evaluation and impact assessment.

ILRI INTERNATIONAL LIVESTOCK RESEARCH INSTITUTE

IFPRI

IITA Research to Nourish Africa

Implementation strategy

Total LandCare (TLC) was chosen as a partner in this research project due to their long track record of promoting conservation agriculture (CA) projects in Malawi. Total LandCare has a strong infrastructure in Malawi enabling TLC to manage day-to-day project activities. Farmers willing to participate in this study were chosen in collaboration with TLC field staff. Participating farmers had already implemented some CA techniques on their farms with assistance from TLC. Crops grown in each district were chosen after consultation with farmers and TLC field staff to choose crops best suited to agro-ecological and economic conditions in each district.

Bunda College (Lilongwe University of Agriculture and Natural Resources) was chosen has a partner because it has a long history of co-operation with Washington State University (WSU) and because of its laboratory capabilities in the areas of soil and plant analysis. Also, by partnering with Bunda College we are able to increase the capacity of Bunda College laboratories, improving its ability to service its researchers and students.

Washington State University research staff met with TLC monthly to ensure that all project activities were proceeding in a timely manner. Monthly meetings between WSU and Bunda College ensured timely analysis of samples. Additionally, WSU research staff visited all on-farm research sites monthly to evaluate progress of the research and to meet with participating farmers.

Implemented work program and results per output and activity

Output 1. Evaluate the suitability of maize, sweet potato, and cassava has a rotation crops in CA systems	
Activity 1.1 Analysis of Food Production	Participating farmers harvested sweet potato and cassava leaves as green vegetables in April and May. Leaf harvests per households were recorded and samples of sweet potato and cassava leaves collected. In May continuous no-till maize plots were harvested in Dowa and Nkhotakota districts. Yield data was recorded and maize samples were collected. In Dowa, sweet potatoes in conservation agriculture and conventional rotation plots were harvested in May. Yield data was recorded and sweet potato samples were collected. Yield data is presented in Table 1. Cassava yield data will be collected in November 2012 and reported before December 31, 2012. All crop residues will be analyzed for total biomass production and N and C content and results will be reported by December 31, 2012. Sweet potato grown in the CA system performed poorly relative to conventionally grown sweet potatoes.
Activity 1.2 Analysis of nutritional outputs	Due to capacity problems in the human nutrition laboratory at Bunda College, we will not be able to conduct laboratory analysis of nutritional output from each crop grown. Therefore, yield data for all crops grown will be 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 the Dowa district is presented in Table 2, and the nutritional output per hectare in Nkhotakota district will be completed by December 31, 2012 once cassava harvest is complete.
Activity 1.3 Analysis of soil quality and fertility	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, organic C, inorganic N (NO_3^- + NH_4^+), available P, K, Ca, Mg, and Zn (Table 4)
Activity 1.4 Analysis of farming system resilience to drought and climate	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 was downloaded monthly. In Dowa, final soil moisture and temperature data collection and removal of sensors was completed in May 2012, at sweet potato harvest. Soil moisture sensors in Nkhotakota district remain in situ until cassava harvest November 2012. Soil

variability and change	moisture and temperature data from Nkhotakota district has been recorded up to August 25, 2012. Soil moisture and temperature data are presented in Figures 1 and 2. In Dowa district farmers did not practice residue retention has part of their CA systems, whereas in Nkhotakota district farmers did maintain residue has surface mulch. The presence of surface mulch greatly increase soil moisture content relative to the plots without surface mulch.
Output 2. Evaluate the impact of intercropping pigeon pea on household nutrition and income	
Activity 2.1 Analysis of pigeon pea production	Pigeon pea was intercropped in the CA plots with sweet potato (Dowa) and cassava (Nkhotakota). Pigeon peas were harvested between late June and early August. The farmers determined that harvesting in multiple stages was more efficient and reduced insect damage compared to waiting for all the pods to reach maturity. Harvest data was recorded and samples collected at each harvest date (Table 1). Pigeon pea plants were left standing in the field to offer living vegetative cover and will biomass samples will be collected in November 2012 and reported by December 31, 2012.
Activity 2.2 Analysis of pigeon pea contributio n to nutrition and household income	Pigeon pea nutritional output data from the USDA National Nutrient Database (http://www.ars.usda.gov/Services/docs.htm?docid=8964) was used to determine the total nutritional output of pigeon pea for each district (Table 6).
Output 3. Economic analysis of different cropping systems	
Activity 3.1	We used partial budget analysis techniques to do an economic analysis of the benefit:cost ratio of each farming system. Input prices--seed, fertilizer, and herbicides--were priced based on retail prices at trading centers and towns near each research site at the time of planting. Labor costs were determined using both opportunity cost and daily wages. Labor costs for the opportunity cost method were determined by interviewing farmers about the price of hiring labor to perform each farm operation instead of using household labor. For the daily wage method, the labor days (8 hour days) needed to complete each farm operation was recorded by either the research team or the farmers themselves. A daily wage of 1.5x Malawi's minimum daily wage was then 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 no-till maize plots in Dowa and

	Nkhotakota are presented in Table 7, and CA and conventional rotation plots in Dowa in Table 8. Cassava will be harvested in November 2012. Once harvest is complete we will complete the cost:benefit analysis for the CA and conventional rotation plots in Nkhotakota and will report the results by December 31, 2012. The Dowa district sites are rural with lower market access, whereas Nkhotakota sites have better market access. The location of the sites had a significant impact on the profitability of each cropping system when comparing the opportunity cost and daily wage labor prices.

Output 4. Increased capacity of Bunda College's soil analytical laboratory to analyse soil and plant samples	
Activity 4.1	All soil samples were analysed at the Bunda College soil analytical laboratory. Fees paid to the laboratory will help to enhance the laboratories capacity. Additionally, in order to conduct certain procedures, laboratory equipment was purchased for the laboratory. This equipment includes a hot plate and test tubes to conduct Kjedhal N analysis.

Measurable outputs/deliverables

(a) People trained:

Four farmers in the Nkhotakota district and three farmers in the Dowa district were trained in improved soil and crop management techniques. Additionally, 2 research assistants were trained in laboratory analysis and field research techniques.

(b) Technologies introduced:

Three new crop management strategies were introduced to seven farmers. These technologies include conservation agriculture management of sweet potato in Dowa district, conservation agriculture management of cassava in Nkhotakota district, and pigeonpea intercropping in conservation agriculture systems in both Nkhotakota and Dowa districts.

Links with other research and development projects

Strong collaboration between CIMMYT, WSU, TLC and Bunda College will help dissemination of project outcomes widely in Malawi and the region. Moreover, TLC has an extensive network of field staff that has been successfully implementing CA programs in Malawi, Mozambique, Tanzania, and Zambia, since 2004. Strong collaboration between TLC and the research team will allow for positive project results to be incorporated into other TLC led conservation agriculture programs.

Concluding remarks

This project is on-going, with cassava harvest in the CA and conventional rotation plots scheduled for November 2012. Once cassava is harvested we will complete our food production and economic analysis and final reporting by December 31, 2012.

Challenges: Analysis of samples at Bunda College was delayed due to power and water shortages and poor analytical capabilities. Therefore, we had to re-evaluate our measured parameters to include only those that we are capable of completing at Bunda College. This involved eliminating food quality analysis and using the USDA nutrient database to develop or nutritional outcome tables. Also, erratic rainfall delayed planting of sweet potato in Dowa district, which resulted in low sweet potato yields.

Lessons Learned: Lower sweet potato yields in CA compared to conventional rotation suggests that more research needs to be done to develop strategies to successfully incorporate sweet potato into CA systems. Despite low yields, there were still nutritional gains over maize with regard to certain vitamins and minerals, making sweet potato an important rotation crop for improving household nutritional outcomes. Additionally, crop residue retention in CA was important in improving soil water content in Nkhotakota district, whereas in Dowa district the lack of residues resulted in poor soil moisture retention. Therefore, crop residue retention in CA is an important component of resilience to drought and climate variability.

Tables and Figures

Table 1. Crop yields by treatment. Cassava will be harvested in November 2012.

District	Treatment	Crop	Yield
Dowa	No-till	Maize	3,641 kg ha^{-1}
	Conservation Agriculture	Sweet potato	6,864 kg ha^{-1}
		Sweet potato leaves	38 kg ha^{-1}
		Pigeon pea	27 kg ha^{-1}
	Conventional Rotation	Sweet potato	9,131 kg ha^{-1}
		Sweet potato leaves	38 kg ha^{-1}
Nkhotakota	No-till	Maize	4,136 kg ha^{-1}
	Conservation Agriculture	Cassava	na
		Cassava leaves	83 kg ha^{-1}
		Pigeon pea	93 kg ha^{-1}
	Conventional Rotation	Cassava	na
		Cassava leaves	80 kg ha^{-1}

Table 2. 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 3. Soil physical properties by district and soil depth (soil texture) and treatment and soil depth (bulk density)

	Nkhotakota			Dowa		
	Soil texture (%)					
Depth (cm)	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	CVR	NT	CA	CVR
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 CVR = conventional rotation

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

Table 4. Soil chemical properties by treatment and soil depth

Parameter	Depth (cm)	Nkhotakota			Dowa		
		NT[z]	CA	CVR	NT	CA	CVR
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
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 CP = conventional practice

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

Table 5. Pigeon pea nutritional output by district

		Dowa	Nkhotakota
Nutrient	Unit ha^{-1}	27 kg ha^{-1}	93 kg ha^{-1}
Energy	Mj	388[z]	1,336
Protien	kg	6	20
Total lipid	kg	0.4	1.4
Carbohydrate	kg	17	58
Fibre, total dietary	kg	4	14
Minerals			
Calcium	g	35	121
Iron	g	1	5
Magnesium	g	49	170
Phosphorus	g	99	341
Potassium	g	376	1,295
Sodium	g	5	16
Zinc	g	0.7	2.6
Vitamins			
Thiamin	g	0.17	0.60
Riboflavin	g	0.05	0.17
Niacin	g	0.8	2.8
Vitamin B-6	g	0.08	0.26
Folate	g	123	424
Vitamin A	g	0.27	0.93

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

Table 7. 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	1.75	6.8	11.81	28.46	1.75	0	0	0
Planting Maize	Day	1.75	34.3	59.82	142.30	1.75	21.9	38.24	35.06
Fertilizer Application (2x)	Day	1.75	20.1	35.13	199.37	1.75	17.7	30.79	70.13
Weeding (2x)	Day	1.75	58.2	101.59	289.04	1.75	63.3	110.44	72.90
Herbicide Application (2x)	Day	1.75	1.6	2.73	57.11	1.75	1.3	2.24	36.17
Harvesting	Day	1.75	20.7	36.17	120.09	1.75	17.8	30.98	88.76
Total Labour Costs	Days		**141.8**	**247.25**	**836.38**		**121.9**	**212.69**	**303.03**
Total Transportation Costs				**8.86**				**11.80**	
Total Variable Costs				**605.06**	**1194.19**			**546.87**	**637.22**
Net Returns				**356.86**	**-232.27**			**215.25**	**124.91**
Benefit:Cost Ratio				**1.59**	**0.81**			**1.39**	**1.20**

Table 8. 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	764.46	
Sweet Potato Leaves	400 g	0.14	94	13.12		94	13.12	
Pigeon Pea	Kg	1.40	27	37.67		-	-	
Vine Transplants	Bundles	2.33	39	90.70		39	90.70	
TOTAL REVENUE				**716.15**			**868.27**	
VARIABLE COSTS								
Inputs								
Sweet Potato Vine	Bundle	2.33	154	358.14		154	358.14	
Pigeon Pea Seed	Kg	1.98	1	1.98		-	-	
Fertilizer (23:21:0:4)	50kg bag	39.16	2.5	97.90		2.5	97.90	
Roundup	L	13.49	2.5	33.72		-	-	
Total Input Costs				**491.73**			**456.03**	
Labour Costs		**(8 hr day)**	**Daily Labour**		**Opportunity Cost**	**Daily Labour**		**Opportunity Cost**
Tilling Ridges	Day	1.75	-	-	-	35.3	61.63	45.86
Planting Sweet Potato	Day	1.75	20.0	34.85	35.06	15.5	27.08	35.06
Planting Pigeon Pea	Day	1.75	3.2	5.64	17.03	-	-	-
Fertilizer Application	Day	1.75	5.3	9.31	35.06	5.1	8.95	35.06
Weeding (2x)	Day	1.75	71.5	124.73	83.32	46.0	80.25	39.31
Herbicide Application	Day	1.75	0.9	1.62	21.32	-	-	-
Harvesting Sweet Potato	Day	1.75	18.1	31.62	110.45	14.5	25.32	97.71
Harvesting Pigeon Pea	Day	1.75	1.2	2.14	10.55	-	-	-
Total Labour Costs	Days		**120.3**	**209.91**	**312.79**	**116.5**	**203.23**	**253.01**
Transportation Costs				**9.91**			**9.91**	
Total Variable Costs				**711.55**	**814.43**		**669.17**	**718.95**
Gross Margins				**4.60**	**-98.28**		**199.10**	**149.32**
Benefit:Cost Ratio				**1.01**	**0.88**		**1.30**	**1.21**

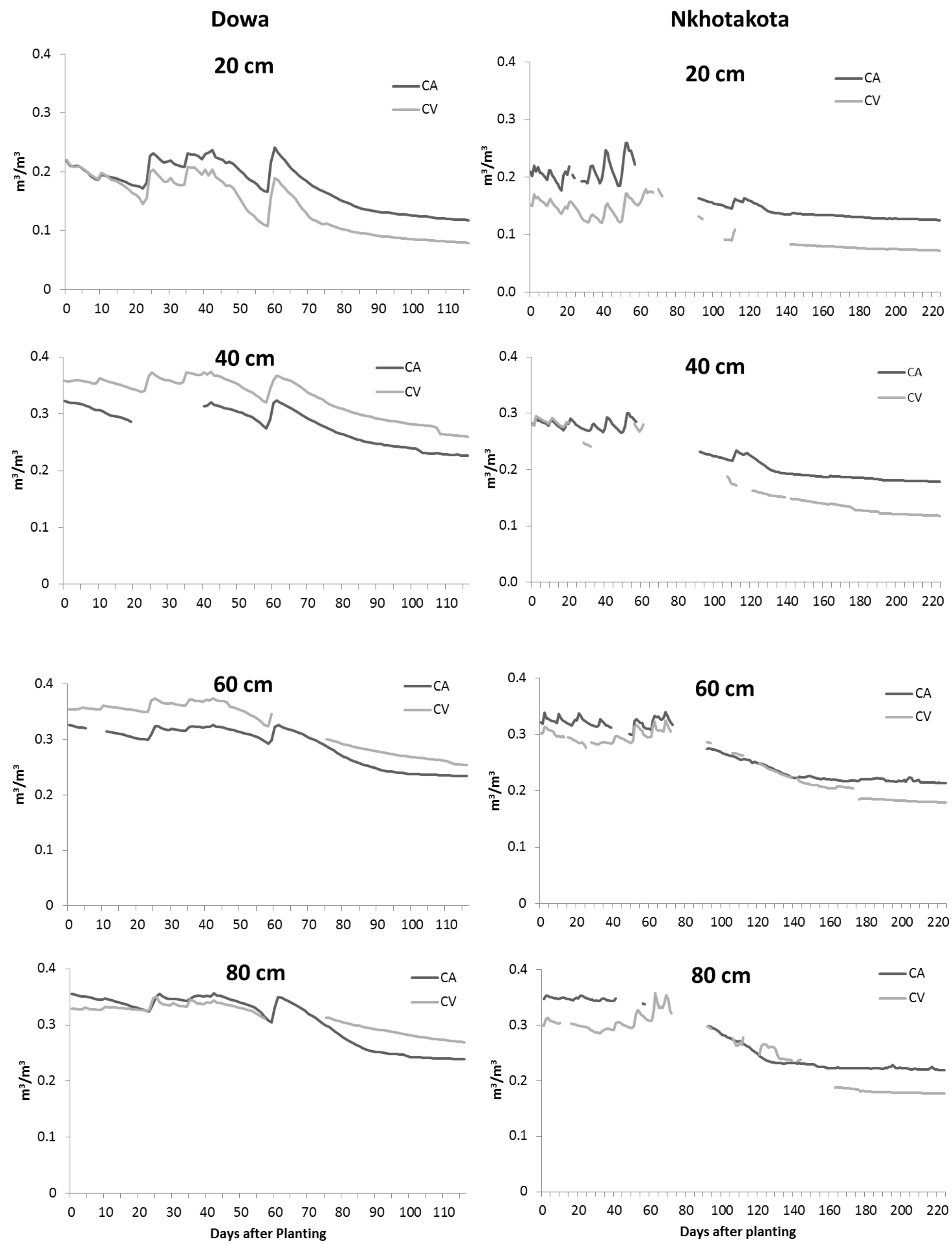

Figure 1. Soil moisture content at 20 cm, 40 cm, 60 cm, and 80 cm in Dowa (left) and Nkhotakota (right) for conservation agriculture (CA) and conventional rotation (CV). Conservation agriculture plots in Dowa did not have crop residue cover.

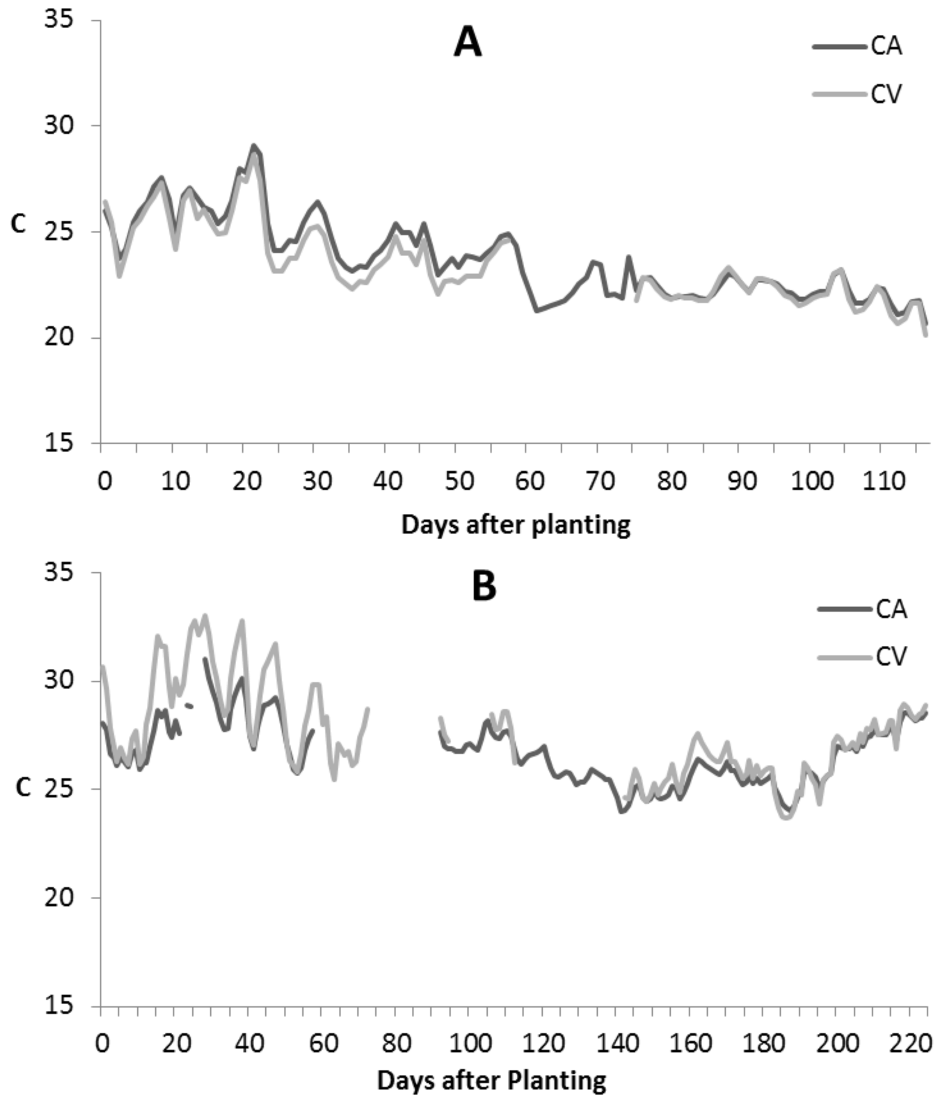

Figure 2. Soil temperature at 20 cm in A) Dowa and B) Nkhotakota for conservation agriculture (CA) and conventional rotation (CV). Conservation agriculture plots in Dowa did not have crop residue cover.