The Effect of Reduced Tillage and Mineral Fertilizer Application on Maize and Soybean Productivity in Kenya

By Job Kihara and Samuel Njoroge

Conservation Agriculture (CA) has been promoted for adoption by smallholder farmers in maize-based cropping systems in sub-Saharan Africa with limited success, mainly due to a reduction in crop yields in the initial years of transition from conventional tillage (CT) to CA. Results from this study confirmed the initial yield reduction with CA and showed that at least six seasons were required for maize yields under CA to match those under CT. However, soybean yields were not affected by tillage practice and may offer opportunity to accelerate the agronomic benefits of CA in rotation and intercrop systems.

Conservation agriculture, based on reduced tillage (RT) and surface retention of crop residues, offers smallholder farmers in sub-Saharan Africa an opportunity to reverse land degradation that is prevalent in the region and support sustainable intensification of crop production (Fowler and Rockstrom, 2001). Conservation agriculture has been found to enhance physical, biological, and chemical properties of the soil when compared to CT practices (Madari et al., 2005). Despite the benefits of CA on soil quality restoration, adoption among farmers in Kenya and elsewhere in sub-Saharan Africa has been low (Rockstrom et al., 2003). Among the reasons for low adoption of CA by smallholder farmers is the initial lower crop productivity associated with CA compared to CT commonly practiced by farmers (Taa et al., 2004).

A long-term on-farm experiment was established in 2003 to investigate the effect of tillage and crop residue application on maize and soybean productivity over different cropping seasons in the sub-humid zone of western Kenya. The aim of the study was to identify cropping systems that may offer opportunities to enhance the soil fertility benefits of CA, while preventing the initial depression of yields associated with the transition from CT. The experiment was conducted over nine seasons from 2003 to 2007.

Soils in the study site had the following characteristics: 64% clay, 15% sand, pH (water) 5.1, 1.35% SOC, 0.15% N, and 3.0 mg/kg available P. The mean annual rainfall is 1,800 mm and occurs in two seasons: long rains from March to August and short rains from September to January.

A cooperating farmer in western Kenya planting maize in the conservation tillage plots.

The experiment was set up as a split-split-split plot design with four replicates and had a factorial combination of tillage system (reduced and conventional tillage), crop residue management (+/- crop residue) and cropping system (continuous cereal, soybean-maize rotation and soybean-maize intercrop). All plots received a blanket application of 60 kg P/ha and 60 kg K/ha each year. Additionally, the maize crop in the monocrop and maize-soybean rotation systems received 60 kg N/ha. No N was applied to the maize-soybean intercrop system. Maize residues were applied seasonally at 2 t/ha before planting. The maize residues were left on the surface in RT plots and incorporated in CT plots. Soybean residues were not removed after harvesting, and were either incorporated in the CT treatment or left on the surface in the RT treatment. Maize was planted at a spacing of 0.75 m x 0.25 m with one plant per hill. Soybean was planted at 0.05 m x 0.75 m.

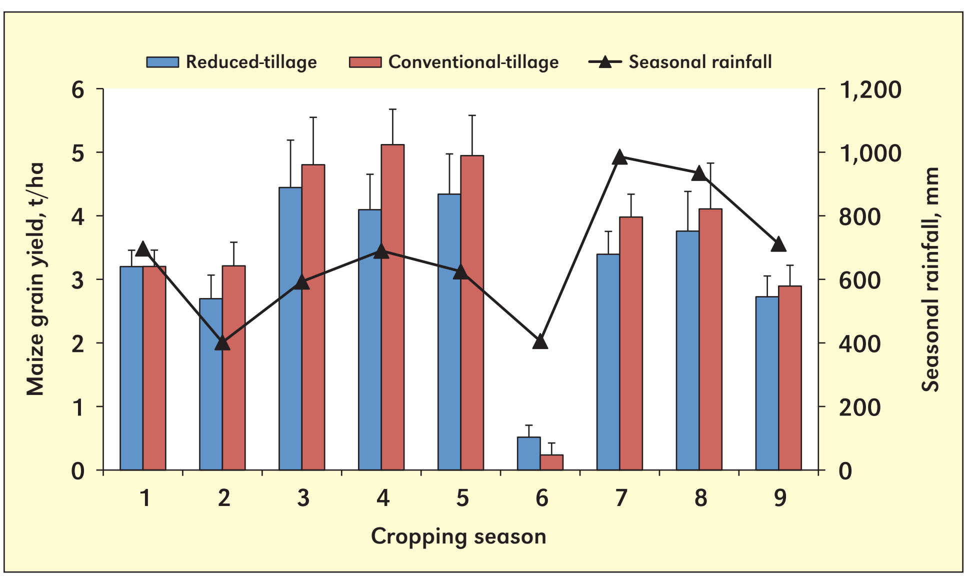

Figure 1. Maize grain yield in reduced and conventional tillage as observed in continuous maize cropping system in Nyabeda, western Kenya, from March 2003 to August 2007.

Common abbreviations and notes: N = nitrogen, P = phosphorus, SOC = soil organic carbon, USD = United States dollar.

Table 1. Maize yield in continuous maize, soybean-maize rotation, and soybean-maize intercropping in Nyabeda, western Kenya, March 2003 and August 2007.

Treatment	Continuous maize	Rotation	Intercrop
	- - - - - - - - - - - - - t/ha - - - - - - - - - - - - -		
Reduced tillage -CR	3.24 c	3.18 b	1.75 b
Reduced tillage +CR	3.58 bc	3.00 b	1.89 b
Conventional tillage -CR	3.97 ab	3.91 a	2.77 a
Conventional tillage +CR	4.07 a	3.74 a	2.58 a
SE	0.20	0.20	0.16
Tillage	**	**	**
Tillage x Crop residue	-	-	-

Numbers in the same column followed by a different letter are significantly different at $p<0.05$; CR = crop residue; SE = standard error; **significant at $p<0.01$; Season 6 was not included due to crop failure as a result of drought.

Table 2. Average soybean yield (t/ha) in soybean-maize rotation and intercropping systems in Nyabeda, western Kenya, March 2003 and August 2007.

Tillage	Crop residue	Rotation	Intercrop
Reduced tillage	-CR	0.95	0.56
Reduced tillage	+CR	0.92	0.60
Conventional tillage	-CR	0.99	0.52
Conventional tillage	+CR	0.98	0.53
SE		0.107	0.092

CR = crop residue; all treatments received 60 kg P/ha but not N; season 1 (common beans) and crop failure season (season 6) not included; SE = standard error.

The crop spacing was maintained for the intercrop system. Analysis of variance for maize yield data was conducted using Statistical Analysis Software (SAS). Gross margin was calculated as the difference between gross revenue and total variable costs (**Table 3**).

Maize Yields

There was no significant effect of crop residue addition on maize yield and only small variations (-9 to +11%) were observed. This is in agreement with the finding of Erenstein (2003) that there are no clear immediate benefits of crop residue in sub-humid environments. However, addition of crop residues may improve maize yields in the long-term, as improved soil structure with addition of crop residues was observed for this site (see Kihara et al., 2012).

Maize yields varied from year-to-year due to variability in seasonal rainfall (**Figure 1**). Average maize yields for the nine seasons, were 3.2 to 4.1 t/ha in continuous maize, 3.0 to 3.9 t/ha in soybean-maize rotation and 1.8 to 2.8 t/ha in the soybean-maize intercropping system (**Table 1**). CT resulted in 11 to 26%, 17 to 30%, and 36 to 58% higher maize yields than RT, in continuous maize, soybean-maize rotation and intercropping systems, respectively. Although yields for CT were initially higher than under RT in the continuous maize and rotation systems, there were no significant differences in yields observed during the last three seasons. A time lag of six seasons was therefore necessary for maize yields in RT to match those in CT systems. The improved performance of RT after six seasons is likely due to soil improvement under reduced tillage, including soil structure as reported in Kihara et al., 2012. This is consistent with other studies which have reported initial lower yields in RT compared with CT systems and increased RT yields after several seasons of continued practice (Malhi et al., 2006). For the intercrop systems, higher yields were consistently produced under CT than RT. Maize yields were lower for the intercrop systems compared to the monocrop and rotation systems as no N fertilizer had been applied and the possible competition from the associated soybean crop.

Table 3. Average seasonal gross margins of different tillage and crop residue combinations in different cropping systems in Nyabeda, western Kenya, from March 2003 to August 2007.

Treatment	Cropping system	Gross margin*, USD/ha	SE
Reduced tillage -CR	Maize monocrop	247	165
Reduced tillage +CR	Maize monocrop	289	105
Conventional tillage -CR	Maize monocrop	322	143
Conventional tillage +CR	Maize monocrop	322	137
Reduced tillage -CR	Intercrop	344	254
Reduced tillage +CR	Intercrop	374	313
Conventional tillage -CR	Intercrop	435	393
Conventional tillage +CR	Intercrop	401	347
Reduced tillage -CR	Rotation	337	216
Reduced tillage +CR	Rotation	305	211
Conventional tillage -CR	Rotation	384	171
Conventional tillage +CR	Rotation	359	195

SE = standard error.
*The gross margin analysis was based on 2007 prices (USD) for harvested grain including: $185.50/t for maize and $694.40/t for soybean. Crop input prices included $690/t for maize seed, $690/t for soybean seed, $444/t for urea, $514/t for triple super phosphate, and $590/t for potassium chloride.

Soybean Yields

Average soybean yields ranged between 0.92 to 0.99 t/ha in the soybean-maize rotation, and between 0.52 to 0.60 t/ha in the soybean-maize intercropping system (**Table 2**). Although soybean yields were expected to respond to tillage and crop residue management as observed with maize yield, no such effects were observed. The lack of differences can be attributed to faster establishment and maximum canopy (reaching up to 100% in about two months after planting), which completely covered the soil and protected soil water from surface evaporation. The soil under the bushy soybean was observed to be wetter than in the other cropping systems. The similar soybean yields under RT and CT suggest that including soybean in rotation with maize in RT systems could reduce the overall yield losses in the initial years of establishment of RT.

Profit Analysis

Conventional tillage gave higher mean gross margins than

RT for the nine seasons under the three cropping systems. Average annual gross margins over the nine seasons ranged from USD 247 in the continuous cereal (RT minus crop residue) to USD 435 in the soybean-maize intercropping system (CT minus crop residue) (**Table 3**). These gross margins were influenced by the cropping system and were in the order intercropping > rotation > continuous maize. Although savings in labor in RT lowered the costs of production, this could not compensate for the reduced income from lower yields in the RT system. Longer time periods (> nine seasons) are required to make RT economically viable for farmers, and this is one of the key factors discouraging wide-scale adoption of conservation agriculture in mixed maize and legume-based smallholder farming systems.

Summary

RT with application of residues resulted in soybean yields comparable to CT system treatments, for rotation and intercrop systems, with no yield reduction observed over nine seasons. However, maize yields were initially suppressed in RT treatments under monocrop, rotation and intercrop systems, and at least six seasons of continued RT practice were required for the yields to match those under CT. The lower yields under RT resulted in lower mean gross margins for nine cropping seasons, and this is a disincentive for farmers to switch from conventional tillage to conservation tillage. More work is required to develop effective management practices to control weeds and to supply greater soil cover in the RT system to avoid soil-crusting problems which lead to the initial lower maize yields with RT under smallholder condition in sub-Saharan Africa. BC

Acknowledgement

This article was originally published as J. Kihara, A. Bationo, B. Waswa, JM Kimetu, B. Vanlauwe, J. Okeyo, J. Mukalama and C. Martius (2012). Effect of reduced tillage and mineral fertilizer application on maize and soybean productivity. Experimental Agriculture 48:159-175.

Dr. Kihara is a Researcher at the Tropical Soil Biology and Fertility Institute of the International Center for Tropical Agriculture; e-mail: j.kihara@cgiar.org. Mr. Njoroge is a Research Assistant at the Tropical Soil Biology and Fertility Institute of the International Center for Tropical Agriculture; e-mail: s.kinyanjui@cgiar.org.

References

Erenstein, O. 2003. Agriculture, Ecosystems and Environment 100:17-37

Fowler, R. and J. Rockstrom. 2001. Soil & Tillage Research 61: 93-107.

Kihara, J., C. Martius, A. Bationo, M. Thuita, D. Lesueur, L. Herrmann, W. Amelung, and P.L.G. Vlek. 2012. Applied Soil Ecology 58:12-20

Madari, B., P.L.O.A. Machado, E. Torres, A.G. de Andrade, and L.I.O. Valencia. 2005. Soil & Tillage Research 80:185-200.

Malhi, S.S., R. Lemke, Z.H. Wang, and B.S. Chhabra. 2006. Soil & Tillage Research 90:171-183.

Rockstrom, J., P. Kaumbutho, P. Mwalley, and M. Temesgen. 2003. *In* García-Torres L, Benites J, Martínez-Vilela A, Holgado-Cabrera A (eds.). Conservation agriculture. Kluwer Academic Publishers, Dordrecht, London, pp 459-470.

Taa, A., D. Tanner, and A.T.P. Bennie. 2004. Soil & Tillage Research 76:69-82.

UNITED STATES POSTAL SERVICE®

Statement of Ownership, Management, and Circulation (Requester Publications Only)

1. Publication Title: Better Crops with Plant Food
2. Publication Number: 0 0 0 6 – 0 0 8 9
3. Filing Date: October 15, 2012
4. Issue Frequency: Quarterly
5. Number of Issues Published Annually: 4 (four)
6. Annual Subscription Price *(if any)*: Free to Subscribers
7. Complete Mailing Address of Known Office of Publication *(Not printer) (Street, city, county, state, and ZIP+4®)*: 3500 Parkway Lane, Suite 550, Norcross, GA 30092-2844
   Contact Person: Gavin Sulewski
   Telephone *(Include area code)*: 770-825-8080
8. Complete Mailing Address of Headquarters or General Business Office of Publisher *(Not printer)*: International Plant Nutrition Institute, 3500 Parkway Lane, Suite 550, Norcross, GA 30092-2844
9. Full Names and Complete Mailing Addresses of Publisher, Editor, and Managing Editor *(Do not leave blank)*
   Publisher *(Name and complete mailing address)*: Gavin Sulewski, International Plant Nutrition Institute, 3500 Parkway Lane, Suite 550, Norcross, GA 30092-2844
   Editor *(Name and complete mailing address)*: Gavin Sulewski, 3500 Parkway Lane, Suite 550, Norcross, GA 30092-2844
   Managing Editor *(Name and complete mailing address)*
10. Owner *(Do not leave blank. If the publication is owned by a corporation, give the name and address of the corporation immediately followed by the names and addresses of all stockholders owning or holding 1 percent or more of the total amount of stock. If not owned by a corporation, give the names and addresses of the individual owners. If owned by a partnership or other unincorporated firm, give its name and address as well as those of each individual owner. If the publication is published by a nonprofit organization, give its name and address.)*

Full Name	Complete Mailing Address
International Plant Nutrition Institute	3500 Parkway Lane, Suite 550, Norcross, GA 30092-2844

11. Known Bondholders, Mortgagees, and Other Security Holders Owning or Holding 1 Percent or More of Total Amount of Bonds, Mortgages, or Other Securities. If none, check box ▶ ■ None

Full Name	Complete Mailing Address

12. Tax Status *(For completion by nonprofit organizations authorized to mail at nonprofit rates) (Check one)*
   The purpose, function, and nonprofit status of this organization and the exempt status for federal income tax purposes:
   ■ Has Not Changed During Preceding 12 Months
   ☐ Has Changed During Preceding 12 Months *(Publisher must submit explanation of change with this statement)*

PS Form **3526-R,** August 2012 *(Page 1 of 3 (Instructions Page 3))* PSN: 7530-09-000-8855 **PRIVACY NOTICE:** See our privacy policy on www.usps.com.

13. Publication Title: Better Crops with Plant Food
14. Issue Date for Circulation Data Below: November, 2012

15. Extent and Nature of Circulation			Average No. Copies Each Issue During Preceding 12 Months	No. Copies of Single Issue Published Nearest to Filing Date
a. Total Number of Copies *(Net press run)*			13,200	13,075
b. Legitimate Paid and/or Requested Distribution *(By Mail and Outside the Mail)*	(1)	Outside County Paid/Requested Mail Subscriptions stated on PS Form 3541. *(Include direct written request from recipient, telemarketing, and Internet requests from recipient, paid subscriptions including nominal rate subscriptions, employer requests, advertiser's proof copies, and exchange copies.)*	1,693	1,286
	(2)	In-County Paid/Requested Mail Subscriptions stated on PS Form 3541. *(Include direct written request from recipient, telemarketing, and Internet requests from recipient, paid subscriptions including nominal rate subscriptions, employer requests, advertiser's proof copies, and exchange copies.)*	0	0
	(3)	Sales Through Dealers and Carriers, Street Vendors, Counter Sales, and Other Paid or Requested Distribution Outside USPS®	3,683	3,613
	(4)	Requested Copies Distributed by Other Mail Classes Through the USPS (e.g., First-Class Mail®)	800	800
c. Total Paid and/or Requested Circulation *(Sum of 15b (1), (2), (3), and (4))* ▶			6,176	5,699
d. Nonrequested Distribution *(By Mail and Outside the Mail)*	(1)	Outside County Nonrequested Copies Stated on PS Form 3541 *(include Sample copies, Requests Over 3 years old, Requests induced by a Premium, Bulk Sales and Requests including Association Requests, Names obtained from Business Directories, Lists, and other sources)*	5,639	5,611
	(2)	In-County Nonrequested Copies Stated on PS Form 3541 *(include Sample copies, Requests Over 3 years old, Requests induced by a Premium, Bulk Sales and Requests including Association Requests, Names obtained from Business Directories, Lists, and other sources)*	0	0
	(3)	Nonrequested Copies Distributed Through the USPS by Other Classes of Mail *(e.g., First-Class Mail, Nonrequestor Copies mailed in excess of 10% Limit mailed at Standard Mail® or Package Services Rates)*	0	0
	(4)	Nonrequested Copies Distributed Outside the Mail *(Include Pickup Stands, Trade Shows, Showrooms, and Other Sources)*	50	50
e. Total Nonrequested Distribution *(Sum of 15d (1), (2), (3) and (4))*			5,689	5,661
f. Total Distribution *(Sum of 15c and e)* ▶			11,865	11,360
g. Copies not Distributed *(See Instructions to Publishers #4, (page #3))* ▶			1,335	1,715
h. Total *(Sum of 15f and g)*			13,200	13,075
i. Percent Paid and/or Requested Circulation *(15c divided by f times 100)* ▶			52.1%	50.2%

16. ☐ **Total circulation includes electronic copies. Report circulation on PS Form 3526-X worksheet.**

17. Publication of Statement of Ownership for a Requester Publication is required and will be printed in the No.4, 2012 issue of this publication.

18. Signature and Title of Editor, Publisher, Business Manager, or Owner: Editor
Date: 10/15/12

I certify that all information furnished on this form is true and complete. I understand that anyone who furnishes false or misleading information on this form or who omits material or information requested on the form may be subject to criminal sanctions (including fines and imprisonment) and/or civil sanctions (including civil penalties).

PS Form **3526-R,** August 2012 *(Page 2 of 3)*