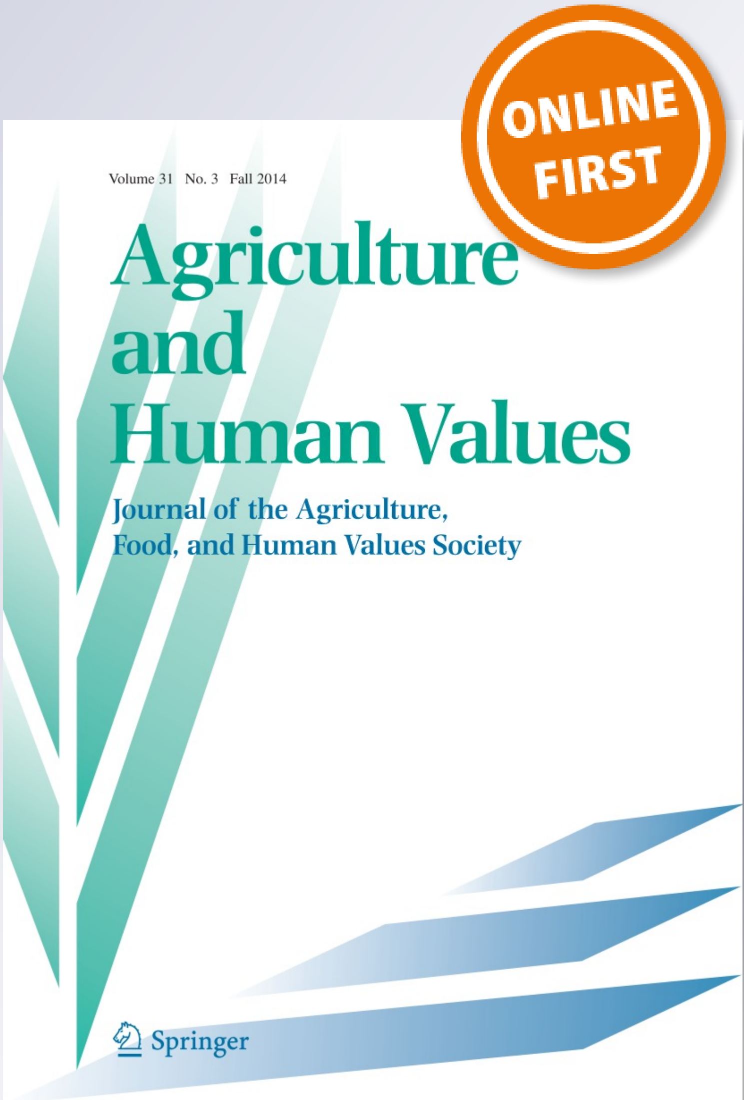
Facing food insecurity in Africa: Why, after 30 years of work in organic agriculture, I am promoting the use of synthetic fertilizers and herbicides in small-scale staple crop production

Don Lotter

Agriculture and Human Values
Journal of the Agriculture, Food, and Human Values Society

ISSN 0889-048X

Agric Hum Values
DOI 10.1007/s10460-014-9547-x



Springer

Agric Hum Values
DOI 10.1007/s10460-014-9547-x

DISCUSSION PIECE

Facing food insecurity in Africa: Why, after 30 years of work in organic agriculture, I am promoting the use of synthetic fertilizers and herbicides in small-scale staple crop production

Don Lotter

Accepted: 25 July 2014

Abstract Food insecurity and the loss of soil nutrients and productive capacity in Africa are serious problems in light of the rapidly growing African population. In semi-arid central Tanzania currently practiced traditional crop production systems are no longer adaptive. Organic crop production methods alone, while having the capacity to enable food security, are not feasible for these small-scale farmers because of the extra land, skill, resources, and 5–7 years needed to benefit from them—particularly for maize. Maize, grown by 94 % of farmers, has substantial nitrogen needs. The most practical ways of satisfying maize nutrient needs is via integrated soil fertility management, a combination of organic and Green Revolution methods. Maize has been shown in research to outyield the indigenous crops millet and sorghum in nearly all situations including drought. Conservation Agriculture (CA) in Africa has two main categories—organic and herbicide-mediated. The organic version of CA, despite years of promotion, has had a low rate of adoption. Herbicide-mediated zero tillage CA via backpack sprayer can substantially increase conventional maize yields while at the same time nearly eliminating erosion and increasing rainwater capture up to fivefold. Glyphosate herbicide is a non-proprietary product produced in Africa and approved for small farm use. The systemic nature of glyphosate allows the killing of perennial grasses that would otherwise need deep plowing to kill. The rooted weed residues protect the soil from erosion. The risks of glyphosate use are substantially outweighed by the benefits of increased food security and crop system sustainability.

D. Lotter (✉)
Institute of Development Studies, St. John's University of Tanzania, P.O. Box 47, Dodoma, Tanzania
e-mail: don@donlotter.net

Keywords Africa food security · Africa agriculture · Sustainable intensification · Integrated soil fertility management · Zero tillage · Organic agriculture

Introduction

Africa is losing its soil and soil nutrients at a rate that can only be described as catastrophically unsustainable according to a plethora of scientific and government sources (AGRA 2013; Panel 2013; Smaling et al. 1997). Soil erosion is a significant factor in this loss, another is nutrient leaching and a third is loss of soil organic matter (OM), all related to continuous cultivation (crop offtake is a fourth). The seriousness of this issue is intensified by the fact that Africa's average of 1 % annual growth in food production is dwarfed by its average of nearly 3 % annual increase in demand for food. By 2030 Africa will only be able to feed a quarter of its population if present trends continue (Global Harvest Initiative 2013).

Numerous reports have promoted organic agriculture as more appropriate for developing countries than high-input capital-intensive Green Revolution methods (Pretty 2006; Badgley et al. 2007; UNEP-UNCTAD 2008). Issues of groundwater contamination by agrichemicals, eutrophication of freshwater and marine environments by fertilizers, and loss of crop genetic diversity (Tilman 1998) have driven the promotion of organic and sustainable methods. More recently the concept of taking appropriate elements from the Green Revolution and combining them with agroecological and organic methods (and vice versa) has been focused on (Pretty 1997). The agricultural development community is now calling this combination of organic methods (manures, legume green manures as well as integrated pest management) and Green Revolution

Published online: 07 October 2014

methods (synthetic fertilizers, herbicides, improved varieties) "sustainable intensification" (Panel 2013) and for crop nutrients "integrated soil fertility management" (Vanlauwe et al. 2010; AGRA 2013).

In this report I discuss how and why my own approach to crop production has taken a similar direction in my work in this drought susceptible and food insecure region of Africa. In particular, I focus on non-transgenic maize production and the use of glyphosate herbicide to reduce or eliminate tillage, in combination with synthetic nitrogen fertilizers and green manure inputs. As someone who has worked in organic agriculture since its popular beginning in the 1970s, I recognize that the addition of glyphosate herbicide in particular into my roster of tools for sustainable crop production may seem an egregious violation of the sustainable agriculture community's values, especially because of that herbicide's current overuse in transgenic crop production (Mortensen et al. 2012). I will argue that the benefits of eliminating tillage and the subsequent buildup of plant residues and soil OM, along with concomitant reduction of soil and nutrient loss via erosion and leaching, far outweigh the risks of use of this non-proprietary and widely available inexpensive chemical.

The Dodoma region of Central Tanzania is semi-arid, rainfall averages 570 mm/year, and has traditionally been inhabited by the Gogo people who have lived by a combination of crop production and livestock keeping (Rigby 1969). The indigenous small grain crops sorghum (*Sorghum bicolor* [L.] Moench) and pearl millet (*Pennisetum glaucum* (L.) R. Br.) have largely been relegated to secondary status by maize (*Zea mays* subsp. mays L.) since its introduction several hundred years ago. Maize is now grown by 94 % of farmers in the Dodoma region, taking two thirds of crop land (Government of Tanzania 2012). Yields of maize are low in Tanzania, averaging 1.4 tons per hectare countrywide and 0.92 t/ha in the Dodoma region (Rowhani et al. 2011). US rain fed maize yields average close to 10 tons per ha. Tanzanian government agronomists say maize yields should be double the current average—3–4 t/ha countrywide and 1.8 t/ha in the Dodoma region (Swai 2014).

Dodoma is one of the most chronically food insecure regions in East Africa, and central Tanzania has some of the highest rates in Africa of maternal anemia and child stunting (USAID 2011; Mosha 2013). Although starvation no longer kills people in Africa's non-war-torn regions—my own observation and experience is that hunger does kill indirectly. People go for weeks without sufficient nutrition, their immune systems become compromised, they get sick and they die at rates that would be considered catastrophic in developed countries. The cause of death is always listed as a well-known disease—malaria, typhoid, TB etc., but they would likely have survived had they been well fed.

The traditional central Tanzanian crop production system

The indigenous farming system in central Tanzania (and much of Africa), was extensive slash and burn with a multi-year fallow period and virtually no inputs. With population growth reducing land for fallow, most farmers have simply transitioned to annual planting of crops on the same piece of land with no or very low inputs. For those who can access fallowed land or bushland, slash and burn is still practiced. Increasingly this is being done on steep and marginal land. Population has quadrupled since the 1960s and is set to double by 2050 and quadruple by the end of the century. Compounding this is the fact that Africa's most important crops are not indigenous—maize, cassava, rice, and beans. Drastic measures are needed to improve African agricultural productivity and sustainability, and many of these measures will be imported technologies.

Traditional indigenous African staple grain crops, sorghum and pearl millet, have largely been replaced by maize, even in the semi-arid central region of Tanzania. Recent research (Rurinda et al. 2014) is calling into question the belief that sorghum and millet are better crops for drought susceptible regions such as Dodoma than maize and therefore should be grown in order to improve food security. The research showed that even in drought years, with or without fertilizer, maize substantially outyields millet and sorghum, by an average of about 50 %, even when bird damage is controlled in the latter two. Adding to this is the problem of Quelea birds (*Quelea quelea* L.) which can devour entire millet and sorghum crops but cannot touch maize. The research appears to support the decision of the vast majority of central region farmers to grow predominantly maize. Sorghum and millet will continue to be important in maintaining diversity of crops and foods, and in improving food security, but they will likely remain secondary, as farmers and food preparers clearly prefer maize.

Conservation agriculture

Recent research from Malawi (Ngwira et al. 2013) showed in a multi-year experiment that zero-tillage, when carried out on small farms using herbicide applied by backpack sprayer and recommended levels of synthetic fertilizers, increased yields of maize by 30–133 % in the region characterized by frequent drought stress (lower rainfall, sandy soils, similar to the Dodoma region). Farmer net returns increased threefold over identically-fertilized maize on conventionally tilled plots. The increase in net returns resulted partly from the lower labor costs of zero tillage.

Ngwira et al. used the term "Conservation Agriculture" (CA) in the title, and some clarification is needed on that popular term, as most of the references to conservation agriculture in Africa refer to an organic version of CA (no herbicide or synthetic fertilizers) that has failed to be adopted by the majority of African farmers subject to years of promotion and trials. According to the FAO CA "Relies on the simultaneous application of three basic principles: (1) minimum soil disturbance or if possible, no tillage; (2) permanent soil cover; and (3) crop rotations or/and associations" (Thiombiano and Meshack 2009) The non-herbicide version of CA in Tanzania has farmers digging some 12,000–27,500 small basins per hectare for placing fertilizer and seed, the lower number for drier areas (IIRR and ACT 2005). The digging must be done during the dry season so that planting can take place as soon as the rains begin.

The organic version of CA, a popular version of which is known as "Farming God's Way"[1], has been promoted for some years now but the farmer adoption results have been disappointing (Giller et al. 2009; Andersson and D'Souza 2014; Umar 2013). Farmers cite the drudgery of digging the basins as the primary negative factor, as the digging must be done when the soil is dry and hard during the off-season (Andersson and Giller 2012; Umar 2013). The most recent report from Tanzania showed only 13 % of targeted farmers adopting the practice after several years of promotion (Mweta 2013).

Maize and nitrogen

Maize is the most voracious of all of the staple crops for nitrogen, and getting enough nitrogen to maize using exclusively organic sources takes skill and resources (Delate 2009). Various factors maintain low soil OM and nutrient status in the current staple crop system of Dodoma region. Unrestricted off-season livestock grazing of crop fields is a traditional community-wide practice in central Tanzania that reduces the effectiveness of green manure crops and the CA practice of conserving plant residues on the soil surface. Crop residues and end-of-season legumes are consumed by livestock, leaving little for the soil. Additionally, there is a traditional underuse of legumes for maintaining soil fertility. This can change with training and education but will take some years to fully integrate. However, even with grazing restricted, legumes in semi-arid areas can generally provide only a very small portion of the nitrogen needs of maize. The skill and investment that it takes to integrate green manure crops into the rotation, especially in semi-arid regions where the season is short and soil water limiting, will take time to develop. Cowpea and pigeonpea are the preferred legumes in this region for integrating or rotating with maize because of their drought adaptedness.

Livestock manure in the amounts that the average African farmer can obtain fall far short of the nitrogen needs of maize. Studies show that East African smallholder farms with livestock generally recover for the soil <7 % of the nitrogen that is excreted, even when piled and saved, and can provide <5 kg/year of nitrogen, <10 % of the requirement of a hectare of maize (Rufino et al. 2007).

The real value of manure and compost is its microbial contribution, especially in combination with cover crops and green manures. The microbes facilitate and modulate the availability of nutrients to the plant and stimulate the plant's defense system against insects and disease (Sanchez et al. 2001). Therefore efforts to include manures, composts, and cover crops should not be discouraged even if their macronutrient contribution is small.

Legume agroforestry and semi-woody green manure crops have potential to contribute virtually all of the nitrogen needs of maize, if only we could skip the 5 years it would take for investment in education, seed production and dissemination, farmer outreach, and then to grow the legumes in small-scale maize fields. In one experiment, 2 years of *Sesbania* doubled maize yields over a six-year period in comparison with continuous unfertilized maize—in other words 4 years of post-Sesbania maize had twice the yield of 6 years of unfertilized maize (Sanchez and Palm 1996). However, it will take a major organizational effort in Tanzania to capacitate small-scale farmers to go for 2 years with a significant part of their land without maize. Additionally, leguminous agroforestry and cover crops require mineral phosphorus inputs (Kang 1993). Alley cropping of leguminous trees such as *Leucaena* and *Gliricidia* has been shown to enable a doubling of maize yields after applying pruned foliage to the soil (Kang 1993), but again the problem is capacitating farmers to plant and care for rows of trees for the 5 years that it takes to reach nitrogen sufficiency in the foliage.

Our issue is food insecurity related to low staple crop yields in both the short and long term and how to deal with getting adequate nutrients to the crop using available tools. This leaves synthetic fertilizers. Only 2 % of farmers in Tanzania's central region use synthetic fertilizers (Government of Tanzania 2012). Numerous problems have beset the fertilizer subsidy programs in Tanzania and other African countries: a trend toward abandoning subsidies for market approaches, corruption, cumbersome bureaucratic procedures, taxes and fees, and poor storage and transport infrastructure being major factors (AGRA 2013). Research

[1] Africans are deeply religious people and many development efforts are made via churches and religion-based outreach. Approximately two-thirds of Tanzanian's are Christian and one-third Muslim.

shows that in Africa the average application of fertilizers increases crop yields by 64 % (Vanlauwe et al. 2010). The problem is that many soils have been so depleted of OM and nutrients as a result of repeated tillage and cropping and grazing with no inputs that a point has been reached in which the soil structure and nutrient holding capacity is so poor that the response of crops to synthetic fertilizers is far below optimal. When drought hits, crops on these soils whither, and added fertilizer barely pays for itself at the end of the season. These are known as low-response soils (Vanlauwe et al. 2010). This is likely a major reason why so many African farmers don't use fertilizers, because they can't see over the "hump" of time it takes to get enough OM into the soil to get a response from fertilizers. Additionally, the farmers who do buy and add synthetic fertilizers often buy the cheapest one—urea—giving rise to phosphorus deficiency. The nutrient gap between nitrogen and phosphorus is seen as an increasingly significant factor in the underyield of staple crops in Africa (van der Velde et al. 2014).

Organic matter is the main input needed to rehabilitate these depleted soils to the point where fertilizers get a good yield response. Eventually, after years of ample nitrogen- and phosphorus-containing OM inputs, the soils become less responsive to synthetic fertilizers again, but this time it is because adequate nitrogen is being released from the OM. This is the point we want to reach someday on African farms. However, it will be a long road to that point, as the OM input needs are substantial and the management of OM for optimal release of nutrients via mineralization demands attention, most of which will be management of soil disturbance via tillage. With the high soil OM decomposition rates of the tropics, zero- and minimum-tillage will play an important role in nutrient management of OM-based systems. This is the nutrient component of my argument for the use of herbicides. The other components are water capture, erosion control, and soil mycorrhizae.

While managing an organic farm in northern Tanzania for an NGO, I encountered farmers in this foreign volunteer-saturated area who said they didn't want to use "toxic" synthetic fertilizers. Their maize was yellowish and stunted from nitrogen deficiency. This issue has food security implications—maize yields can make the difference between hunger and food security for a family. These farmers had been told by foreign volunteers, nearly all of them untrained in agriculture, that fertilizers "poison" the soil—despite the fact that it is very likely that 99 % of the calories that these amply-fed volunteers had consumed in their lives were from crops amply fed with synthetic fertilizers, grown in fields that are to this day still highly productive. Let's set the record straight—synthetic fertilizers at the levels that are recommended for African farmers—60 kg/ha of elemental nitrogen, do not poison the soil (unless they are contaminated with heavy metals, now relatively uncommon). The fertilized soils will not be as healthy and microbially rich and diverse as soils whose nitrogen is supplied by OM, but they are not toxic. Guest workers and volunteers in Africa need to be very careful about what they recommend to farmers, as they are playing with a serious situation of food security.

Rainwater, tillage, and weed management

Elimination of conventional tillage and buildup of crop residues and off-season vegetation on the soil surface typically reduces erosion by 90 % (FAO undated) and substantially improves the retention of soil nutrients by holding those nutrients in the soil OM fraction, whose levels are increased by reduced soil disturbance. Three to five times more rainwater can be captured in non-tilled soils with a residue layer (Thierfelder and Wall 2010), which in semi-arid Africa, can make the difference between good yield and crop failure. The scarce rainfall here commonly comes in intense events, often with just a few rainstorms providing most of the water for the entire season. Anchored plant residues on the soil surface and a higher soil OM content are crucial to capturing and holding this water.

However, the depleted soils issue arises again. As soils become depleted of nutrients and lose their structure (low-response soils) they can't generate the yields needed to leave sufficient residues to significantly reduce erosion and build soil structure, especially when there is off-season grazing. Soils with residue cover below 30 % are susceptible to erosion, and maize yields below 2.5 Mt/ha do not provide the 30 % residual stover cover (Vanlauwe et al. 2014). Average yields in Tanzania are about half that threshold. So we are back to the problem of getting over the hump of getting yields up in the first 2 years. I believe that fertilizer use, in combination with whatever manure and other organic inputs are possible, is the most realistic way of reaching that yield threshold.

There are additional benefits to zero-tillage: crop root symbiotic mycorrhizal fungi are enhanced by the reduced soil disturbance of zero-tillage (Douds et al. 1995). Mycorrhizas have been shown to improve maize performance in drought situations (Auge 2001). Additionally, many of the soils of Africa are geologically old and consist of secondary clays that have a low cation exchange (nutrient holding) capacity. Increased OM provides cation exchange capacity and is important for preventing nutrients from leaching out.

The aggressive stoloniferous perennial grasses of Africa can only be controlled in two ways—by thorough and deep tillage or by systemic herbicides. Glyphosate is a non-proprietary systemic herbicide, now produced in all of the major African countries and available at low cost in even the smallest agriculture shops. It is approved by the Tanzanian government pesticide regulatory agency for use by all farmers. It can be applied via backpack sprayer (with rubber boots and gloves for protection).

Glyphosate was developed in the early 1970s by the Monsanto company and named RoundUp™. Monsanto's commercial patent for the herbicide expired in 2000 and glyphosate is now manufactured by scores of companies around the world. Transgenic (GMO) crops were developed to be resistant to glyphosate in the 1990s and RoundUp is promoted for use on transgenic RoundUp Ready™ crops. This discussion is limited to non-transgenic crops. Glyphosate must be applied to target vegetation approximately 7 days before seeding of non-transgenic crops. Glyphosate is sold over the counter in many states in the US, including California.

Glyphosate adsorbs strongly to soil, preventing leaching to groundwater, and soil microbes rapidly degrade it within a few days (EPA 1993). In the small-scale system this is usually a one-time application before seeding. Subsequent weed control is generally done by hand hoe.

I am fully aware of the reports of negative health effects of glyphosate exposure (Séralini et al. 2014; Poladian 2013), but my risk assessment (and my value system) says that those putative health effects are likely small when it comes to food security and hunger. As long as any consumer in California, one of the strictest places in the world when it comes to agricultural chemicals, can walk into a garden center and buy glyphosate off the shelf I'm not going to try and withhold it from African farmers. Agrichemicals are sold with labels in both English and Swahili and give instructions on safe application.

I have seen how use of glyphosate can allow the productive growth of crops without tillage, saving soil and capturing rain water, and how it can make the difference between hunger and food security. In my view the specter of massive soil loss via erosion and nutrient loss via tillage in Africa in the next decades vastly overshadows the possible health effects of exposure to the chemical. Life expectancy here in the central region is about 45 years—these people hardly get the *opportunity* to get cancer, largely because of food insecurity. New systemic herbicides are likely to be developed and vetted for health issues in the next 10 years. We must assess the risks and benefits of a technology objectively. It seems hypocritical to me to allow automobiles to kill 35,000 people per year in the US (the risk) because of our insatiable desire for speed (the benefit) while at the same time discouraging the use of a chemical whose benefit far outweigh its risks.

The issue of the development of weed resistance to glyphosate is often brought up. This is mainly an issue in transgenic glyphosate-resistant crops in which very large amounts of the herbicide are used year after year. African farmers of non-transgenic crops are unlikely to soon see weed resistance to herbicides, and when they do, there are methods of avoiding the development of resistance by occasionally substituting another class of herbicide for glyphosate (Hartzler 2005).

A week after the glyphosate application crop seed can be planted using a simple dibble stick or jab planter. In areas where grasses have been controlled by repeated tillage, especially in semi-arid regions, there may be precious little plant residue in the first couple of years. This will be exacerbated by off-season livestock grazing typical of most villages. Livestock-proof fencing is too expensive for most farmers, so this is an issue that will persist.

We have seen good crop performance in the first 2 years of glyphosate-mediated zero tillage demonstration plots. In the second year substantially less herbicide was needed, and we expect the weed seed bank to diminish in subsequent years while at the same time the crop residues build up an increasingly thick mulch cover.

Many practitioners of CA in Africa use small-scale animal-drawn or manual zero- and minimum-tillage technology, often from Brazil or of Brazilian design (Shetto and Owenya 2007). The Magoye Ripper is a bullock drawn tool that slices a narrow and relatively deep trench in the soil, without turning the soil over, ostensibly breaking up any hardpan which is left after years of tillage—a known issue here. Practitioners of glyphosate-mediated CA here say that ripping clearly increases yields as a result of better water infiltration as well as root penetration (Swai 2014). Seed and fertilizer are placed in the ripped furrow, sometimes with a bullock-drawn seed and fertilizer drill of Brazilian origin. However, our experience is that these small-scale implements are hard to find in most of Tanzania despite being well-known in the CA community. Nearly all of the agricultural equipment dealers here are geared toward large- and medium-scale farming.

The zero-tillage community worldwide appears to be divided between permanent zero-tillage, which constitutes two-thirds of zero-tilled crop land in South America; minimum-tillage, that is, ripping a narrow slice in the soil without turning it over (plowing); and occasional full-on disk plowing of zero-tilled fields (USA) (Derpsch et al. 2010).

Addressing food insecurity in Africa

Small farmer ability to buy the agrichemical and seed inputs needed for improved crop production is a problem. The organic approach confronts us with a similar challenge—the inability to access and buy green manure crop seed, tree seedlings, sufficient manure or compost, make available extra land, and to wait for the 2–5 years for the organic inputs to fully give a return on investment.

In the Tanzania central region fewer than 1 % of farmers have ever obtained institutional credit (Government of Tanzania 2012). Related to this is that a mere 3 % of Tanzanian non-government land is legally registered, leaving the vast majority of farmers with no legal title to their land. Farmers without land title can't qualify for bank loans, and I will venture that no market-oriented country has ever developed its agriculture without some kind of low-interest credit system for farmers. The many programs introducing micro-credit in Africa may begin to address this problem. The basic model for micro-financing is the group guarantee (social collateral in place of physical or financial collateral) (Brau and Woller 2004), that is, farmers form a group and apply for a single loan.

In the face of these problems and the dire food security outlook for the future, some see large-scale mechanized high input/output agriculture as a solution. To quote the American manager of a large-scale multinational-backed agribusiness in Tanzania: "For 50 years aid agencies have been trying to lift the smallholder from subsistence to surplus—and they've failed" (Keyworth 2013). However, the large-scale route has stumbled here. Issues of foreign "land-grabbing" in Africa for producing food for export have made headlines (Schiffman 2013; Oakland Institute 2011; LEAT 2011). While Tanzanian government officials fly around the world seeking corporate investments in the "vast" Tanzanian agricultural potential, in practice many of the potential investors are hesitant to commit because of foreign and local NGOs' campaigns against land grabbing. Often the investor-targeted lands are inhabited by small farmers who without legal title have only recently moved into plant low-yield maize and graze livestock. Population growth has reduced empty arable lands to zero. The government doesn't have the expertise and resources to implement large-scale high tech agriculture projects and needs to attract foreign investment for them. Despite the prospect of manifold increases in per hectare crop yield via the agribusiness route, and even if the crops are destined for East African markets, I doubt that it would be worth the effort from the foreign investors' point of view. They will continue to be seen as exploiters by a vociferous component of Tanzanian society who are capable of putting up profit-killing obstacles to food production projects.

Medium-scale medium-technology agriculture—utilizing tractors and tractor equipment, capital-intensive inputs, mobile information technology, credit, market information, cooperatives, adapted Green Revolution methods (sustainable intensification) will likely be an important addition to Tanzanian food production. Capacity to go this route may come from the educated class here, many of whom remain unemployed after graduation from post-secondary institutions. This sector of the population is growing with the government-supported growth of university enrollment, and when these graduates realize that the rejection of agriculture by their generation as "backward" and "beneath" their status is a mistake, and that farming can be lucrative, things will pick up.[2] The agriculture sector worldwide has never had a majority of farmers who are in it for the pure love of farming, most are in it for a living first.

Medium-scale mechanized farming appears to fit well into a community of small-scale non-mechanized farmers. Currently many small-scale farmers pay for tractor plowing of their land by tractor-owning neighbors. In a zero tillage scenario this could be done for spraying herbicide, soil ripping, and seed drilling. More common in the central region however is payment for bullock-drawn plowing by small-scale farmers. Animal-drawn equipment for spraying has been developed in South Africa (Fowler 2000).

The lot of the African small farmer will continue to be a major concern as the quadrupling of population here in this century will necessitate agriculture to continue to absorb young people, there being no discernible outlook for industrial growth to absorb them. The national campaign to educate every citizen through secondary school lags far behind the country's needs and expectations and it is the rural poor who are excluded most. With several million people reaching the age of social independence every year, the rural young must each hack out their hectare of land to plant their maize on increasingly marginal lands with no more resources than a hoe, a machete, and saved seed. With the quote above about 50 years of failure of small-scale agriculture being reinforced by what I see around me here, I'm not sure what will work. Social unrest and religious-political extremism are ominous possibilities.

My weekly jog up a small mountain on the outskirts of Dodoma reinforces the statistics on soil loss and environmental degradation. Despite the mountain having been designated as a reserve of the last tropical dry forest in the urban region, local villagers are slashing, burning, making charcoal, and planting their maize on the mountain's slopes, adding to the drastically unsustainable 400,000 ha of forest and Miombo woodland lost in Tanzania every year (Lusekelo 2013), mostly for charcoal for cooking fuel. The local government doesn't seem to care. The young farmers probably know that their plots will only keep soil for a few years before it is lost. Is this a harbinger of the future? Are we going to see the Haiti-ization of Africa in the next couple of decades?

[2] When I suggested the formation of a student Agribusiness Club at St. John's University over 50 students signed up from the freshman class alone. This is a good sign. There are no classes in agribusiness at the university, and few at other universities, as the focus of university here has always been white collar employment either in government or the private sector.

The only route I see out of African food insecurity in the next decade is via sustainable intensification—the use of both agrichemicals and organic methods together. My change from working exclusively with organic methods to the inclusion of conventional agrichemicals in Africa is, I believe, not a change in my values. The well-being of people and the environment are still at the center of my ethos, with the proviso that the long-term care of the environment enhances human well-being. None of the inputs I am promoting are proprietary products that can lock farmers into income-draining payments to foreign companies.

I still believe that organic is best for systems such as vegetable production because it is much more feasible and health enhancing than organic production of staple grains. I also believe in continuing to promote organic agriculture in developed countries due to my belief that we have the scientific and technological wherewithal to become more ecological in our food production and because agrichemicals are overused, as well as because organic agriculture continues be a force in pulling conventional agriculture towards more ecological approaches—albeit usually when an organic technique proves to be more cost effective than the conventional.

References

AGRA. 2013. Africa Agriculture Status Report: Focus on Staple Crops. Alliance for a Green Revolution in Africa (AGRA). Nairobi, Kenya. www.agra-alliance.org. Accessed 18 July 2014.

Andersson, J.A., and K.E. Giller. 2012. On heretics and God's blanket salesmen: Contested claims for Conservation Agriculture and the politics of its promotion in African smallholder farming. In *Contested agronomy: Agricultural research in a changing world*, ed. J. Sumberg, and J. Thompson. London: Earthscan.

Andersson, J.A., and S. D'Souza. 2014. From adoption claims to understanding farmers and contexts: a literature review of Conservation Agriculture (CA) adoption among smallholder farmers in southern Africa. *Agriculture, Ecosystems & Environment* 187: 116–132.

Auge, R.M. 2001. Water relations, drought and vesicular-arbuscular mycorrhizal symbiosis. *Mycorrhiza* 11: 3–42.

Badgley, C., J. Moghtader, E. Quintero, E. Zakem, M.J. Chappell, K. Aviles-Vazquez, A. Samulon, and I. Perfecto. 2007. Organic agriculture and the global food supply. *Renewable Agriculture and Food Systems* 22(2): 86–108.

Brau, J.C., and G.M. Woller. 2004. Microfinance: A comprehensive review of the existing literature. *Journal of Entrepreneurial Finance* 9(1): 1–27.

Delate, Kathleen. 2009. Organic Grains, Oilseeds, and Other Specialty Crops. In *Organic Farming: The Ecological System*, ed. Charles Francis. Monograph #54 American Society of Agronomy.

Derpsch, R., T. Friedrich, A. Kassam, and L. Hongwen. 2010. Current status of adoption of no-till farming in the world and some of its main benefits. *International Journal Agricultural & Biological Engineering* 3(1): 1–25.

Douds Jr, D., L. Galvez, R. Janke, and P. Wagoner. 1995. Effect of tillage and farming system upon populations and distribution of vesicular-arbuscular mycorrhizal fungi. *Agriculture, Ecosystems & Environment* 52: 111–118.

EPA. 1993. Registration Decision Fact Sheet for Glyphosate (EPA-738-F-93-011) R.E.D. FACTS. United States Environmental Protection Agency.

FAO, Undated. Conservation agriculture. In *Optimizing soil moisture for plant production*. FAO Soils Bulletin #79. Food and Agriculture Organization, United Nations.

Fowler, R. 2000. Animal-drawn herbicide applicators for use in smallscale farmer weed control systems. In *Animal power for weed control. A resource book of the Animal Traction Network for Eastern and Southern Africa (ATNESA),* ed. P. Starkey and T. Simalenga, The Netherlands: Technical Centre for Agricultural and Rural Cooperation (CTA), Wageningen. ISBN 92-9081-136-6.

Giller, K., E. Witter, M. Corbeels, and P. Tittonell. 2009. Conservation agriculture and smallholder farming in Africa: The heretics' view. *Field Crops Research* 114(1): 23–34.

Global Harvest Initiative. 2013. Global Agricultural Productivity Report. Global Harvest Initiative. Washington D.C. http://www.globalharvestinitiative.org/index.php/media-resources/studies-reports/. Accessed 18 July 2014.

Government of Tanzania. 2012. National Sample Census of Agriculture: Regional Report—Dodoma Region.

Hartzler, B. 2005. Iowa Glyphosate Resistance in the Cornbelt. State University Dept. of Agronomy Extension publication. December 22. http://www.weeds.iastate.edu/mgmt/2005/pennpaper.shtml Accessed 10 Jan 2014.

IIRR and ACT. 2005. *Conservation agriculture: A manual for farmers and extension workers in Africa*. International Institute of Rural Reconstruction, Nairobi: African Conservation Tillage Network, Harare. ISBN 9966-9705-9-2.

LEAT. 2011. *Land Acquisitions for Agribusiness in Tanzania: Prospects and Challenges.* Lawyers' Environmental Action Team (LEAT) General Publication. Tanzania. http://landwise.landesa.org/record/380.

Lusekelo, P. 2013. Chainsaws massacre Tanzania's green cover. *The Guardian* (Tanzania) 28 September.

Kang, B.T. 1993. Potential for sustainable agroforestry and alley farming in tropical Africa. In *Soil tillage in Africa: needs and challenges*. FAO SOILS BULLETIN 69. ISBN 92-5-103442-7.

Keyworth, M. 2013. The challenges of boosting Tanzania's rice production. BBC News. 23 December. http://www.bbc.com/news/business. Accessed 18 July 2014.

Montpellier Panel. 2013. Sustainable Intensification: A New Paradigm for African Agriculture. London. http://www.ag4impact.org. Accessed 18 July 2014.

Mortensen, D., J. Egan, B. Maxwell, M. Ryan, and R. Smith. 2012. Navigating a critical juncture for sustainable weed management. *BioScience* 62(1): 75–84.

Mosha, T. 2013. Nutrition of women of child-bearing age and young children. Presentation at Feed the Future Food Security Innovation Labs Collaborative Research Programs (CRSP) Council Meeting "Examining Opportunities for Linkages in Collaborative Research, Technology Dissemination and Human Institutional Capacity Development." Morogoro, Tanzania, 7 March.

Mweta, N. 2013. Mapping out factors of conservation agriculture. *The Guardian* (Tanzania) 7 December.

Ngwira, A., C. Thierfelder, and D. Lambert. 2013. Conservation agriculture systems for Malawian smallholder farmers: long-term effects on crop productivity, profitability and soil quality. *Journal of Renewable Agriculture & Food Systems* 28(4): 350–363.

Oakland Institute. 2011. Understanding land investment deals in Africa: Agrisol Energy and Pharos Global Agriculture Fund's land deal in Tanzania. Land Deal Brief. http://www.oaklandinstitute.org. Accessed 18 July 2014.

Poladian, C. 2013. Agrochemicals Linked To Higher Cancer, Birth Defect Rates In Some Argentine Provinces: Report. *International Business Times*. 20 October.

Pretty, J. 2006. Agroecological Approaches to Agricultural Development. World Bank, Washington, DC. https://openknowledge.worldbank.com/handle/10986/9044 Accessed 7 Aug 2014.

Pretty, J. 1997. The sustainable intensification of agriculture. *Natural Resources Forum* 21(4): 247–256.

Rufino, M., P. Tittonell, M. van Wijk, A. Castellanos-Navarrete, R. Delve, N. de Ridder, and K. Giller. 2007. Manure as a key resource within smallholder farming systems: analysing farm-scale nutrient cycling efficiencies with the NUANCES framework. *Livestock Science* 112: 273–287.

Rurinda, J., P. Mapfumo, M. van Wijk, F. Mtambanengwe, M. Rufino, R. Chikowo, and K. Giller. 2014. Comparative assessment of maize, finger millet and sorghum for household food security in the face of increasing climatic risk. *European Journal of Agronomy* 55: 29–41.

Rigby, P. 1969. *Cattle and Kinship among the Gogo: A Semi-pastoral Society of Central Tanzania*. Ithaca & London: Cornell University Press.

Rowhani, P., D. Lobell, M. Linderman, and N. Ramankutty. 2011. Climate variability and crop production in Tanzania. *Agricultural and Forest Meteorology* 151(4): 449–460.

Sanchez, J., T. Wilson, K. Kizilkay, E. Parker, and R. Harwood. 2001. Enhancing the mineralizable nitrogen pool through substrate diversity in long term cropping systems. *Soil Science Society of America Journal* 65: 1442–1447.

Sanchez, P. and C. Palm. 1996. Nutrient cycling and agroforestry in Africa. *Unasylva* No. 185—Forest influences. Forestry Department, FAO.

Schiffman, R. 2013. *Multinationals carving up Africa for food*. Canberra Times: Australia.

Séralini, G., E. Claira, R. Mesnage, S. Gress, N. Defarge, M. Malatesta, D. Hennequin, and J. de Vendômois. 2014. Republished study: Long-term toxicity of a Roundup herbicide and a Roundup-tolerant genetically modified maize. *Environmental Sciences Europe* 26: 14. doi:10.1186/s12302-014-0014-5.

Shetto, R. and M. Owenya. 2007. Conservation agriculture as practised in Tanzania: three case studies. Nairobi. African Conservation Tillage Network, Centre de Coopération Internationale de Recherche Agronomique pour le Développement, Food and Agriculture Organization of the United Nations.

Smaling, E., S. Nandwa, and B. Janssen. 1997. Soil fertility in Africa is at stake! In *Recapitalization of soil nutrient capital in sub-Saharan Africa*, ed. R. Buresh, P. Sanchez, and F. Calhoun, 47–61. CSSA, SSSA, Madison, Wisconsin: American Society of Agronomy.

Swai, E. 2014. *Personal communication*. Hombolo, Dodoma Region, Tanzania: Principal Agricultural Research Officer, Tanzania Agricultural Research Institute.

Thierfelder, C., and P. Wall. 2010. Investigating conservation agriculture (CA) systems in Zambia and Zimbabwe to mitigate future effects of climate change. *Journal of Crop Improvement* 24(2): 113–121.

Thiombiano, L., and M. Meshack. 2009. *Scaling-up conservation agriculture in Africa: Strategy and approaches*. Addis Ababa: FAO Subregional Office for Eastern Africa.

Tilman, D. 1998. The greening of the green revolution. *Nature* 396: 211–212.

Umar, B. 2013. A critical review and re-assessment of theories of smallholder decision-making: a case of conservation agriculture households Zambia. *Renewable Agriculture and Food Systems* 29(3): 277–290.

UNEP-UNCTAD Capacity-building Task Force on Trade, Environment and Development. 2008. Organic Agriculture and Food Security in Africa. United Nations Conference on Trade and Development United Nations Environment Programme United Nations New York and Geneva.

USAID Tanzania. 2011. Improving child and maternal nutrition in Tanzania. USAID Feed the Future. Draft RFA for consultation. Issuance date April 8, 2011.

van der Velde, M., C. Folberth, J. Balkovič, P. Ciais, S. Fritz, I. Janssens, M. Obersteiner, L. See, R. Skalský, W. Xiong, and J. Peñuelas. 2014. African crop yield reductions due to increasingly unbalanced nitrogen and phosphorus consumption. *Global Change Biology* 20: 1278–1288.

Vanlauwe, B., A. Bationo, J. Chianu, K. Giller, R. Merckx, U. Mokwunye, O. Ohiokpehai, P. Pypers, R. Tabo, K. Shepherd, E. Smaling, and P. Woomer. 2010. Integrated soil fertility management: operational definition and consequences for implementation and dissemination. *Outlook on Agriculture* 39(1): 17–24.

Vanlauwe, B., J. Wendt, K. Giller, M. Corbeels, B. Gerard, and C. Nolte. 2014. A fourth principle is required to define Conservation Agriculture in sub-Saharan Africa: The appropriate use of fertilizer to enhance crop productivity. *Field Crops Research* 155: 10–13.

Don Lotter has a Ph.D. in agroecology from the University of California Davis. His dissertation research focused on organic agriculture. He did his post-doctoral work at Rodale Institute, a major center for organic farming research. He has lived and worked in Africa for different periods since the 1960s. For the past five years he has worked in Tanzania, and is currently a senior lecturer at the Institute of Development Studies at St. John's University, Dodoma, Tanzania.