CHAPTER 8

The Unholy Cross: Profitability and Adoption of Climate-Smart Agriculture Practices in Africa South of the Sahara

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[42] We are grateful to the German Federal Ministry for Economic Cooperation and Development (BMZ) for providing funding for this study. We also acknowledge Edward Kato for providing analytical support.

Climate-smart agriculture (CSA) practices aim to achieve three closely related objectives—sustainably increase agricultural productivity, adapt to climate change, and mitigate greenhouse gas emissions. The CSA objectives directly contribute to achieving United Nations Sustainable Development Goals 1 (no poverty), 2 (zero hunger), 13 (climate action), and 15 (life on land). These factors underscore the importance of ensuring widespread uptake of CSA, which will significantly contribute to achieving overarching development objectives in Africa south of the Sahara (SSA), in particular, food security and poverty reduction.

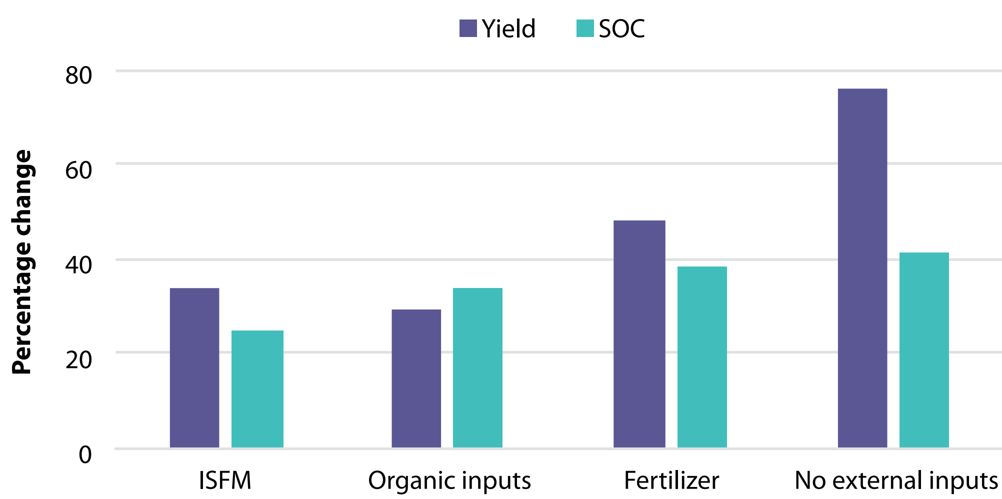
Scaling up the adoption of CSA requires that farmer incentives be taken into account—especially for practices that require significant investment in external and on-farm inputs. Smallholder farmers have particularly limited access to external inputs such as fertilizer, which leads to lower profitability (Chianu, Chianu, and Mairura 2012), lower CSA adoption, and land degradation. For example, over the past 56 years, intensity of fertilizer use—that is, the amount of nutrients used—in SSA has increased from 1 kg/ha of a nitrogen, phosphorus, and potassium blend in 1961 to only 13 kg/ha in 2014 (FAO 2015). The slow growth rate of inorganic fertilizer use has translated into low crop production, plunging the region into being a net food importer since 1980 (Rakotoarisoa, Iafrate, and Paschali 2011).

SSA countries have used different methods to increase fertilizer consumption and consequently food production. The most common method has been fertilizer subsidies, which have increased the rate of fertilizer use. For example, fertilizer use in Zambia increased by 12.5 percent due to subsidies (Druilhe and Barreiro-Hurlé 2012). Fertilizer subsidies have also been shown to increase yield by 12 percent for cotton in Burkina Faso, 41 percent for maize in Ghana, and 32 percent for maize in Nigeria (Druilhe and Barreiro-Hurlé 2012). However, such programs have crowded out private-sector development in input marketing. Across SSA, the cost of these subsidies has become a burden for governments' budgets, making them unsustainable.

This chapter examines the profitability and adoption rates of CSA practices in SSA. We particularly look at strategies that could be used to increase adoption of one particular CSA practice, integrated soil fertility management (ISFM). Other CSA practices include agroforestry, drought-tolerant crops and improved crop varieties, conservation agriculture, integrated crop-livestock management, improved water management, improved pasture and grazing land and water management, restoration of degraded lands, weather early warning systems, and risk insurance (World Bank 2011).

Our results on the adoption and profitability of CSA show an inverse relationship—that is, the adoption rate and profit are inversely related, a pattern that is puzzling and undesired—or, as we refer to it in this chapter, an unholy cross. We begin with a discussion of how ISFM achieves the three CSA objectives. The next section analyzes its profitability and adoption rate, compared with other land management practices, finding a profit-adoption pattern in SSA that is contrary to expectations—the higher the profit, the lower the adoption rate. This is followed by a discussion of the reasons behind this puzzling pattern and a reflection on the policy implications.

FIGURE 8.1—PERCENTAGE DECLINE IN YIELD AND SOIL ORGANIC CARBON, 1972–1993, KENYA LONG-TERM EXPERIMENT



Source: Authors' calculations from unpublished long-term experiment data, Kabete Agricultural Research Institute, Kenya.
Note: ISFM = integrated soil fertility management; SOC = soil organic carbon.

TABLE 8.1—MAIZE YIELD TREND, 1976–1993, KENYA LONG-TERM EXPERIMENT

Treatment[a]	Yield (tons/ha)				% yield increase[b]
	1976	1977–1981	1982–1986	1990–1993	
Control—no inputs	3.80	2.77	2.18	0.91	221
Organic inputs only	3.79	3.89	3.98	2.69	9
Fertilizer only	4.23	4.00	4.21	2.18	34
ISFM	4.43	4.72	4.98	2.92	n.a.

Source: Authors' calculations from unpublished long-term experiment data, Kabete Agricultural Research Institute, Kenya.
Note: a Organic inputs: 5 metric tons per hectare of manure; Fertilizer only: 60 KgN/ha-1 and 60 KgP2O5/ha-1; ISFM: 60 KgN/ha-1, 60 KgP2O5/ha-1, and 5 metric tons per hectare of manure. b Yield increase (percentage) when farmer switches to ISFM from another soil fertility management practice. ISFM = integrated soil fertility management; n.a. = not applicable.

Integrated Soil Fertility Management and Climate-Smart Agriculture Objectives

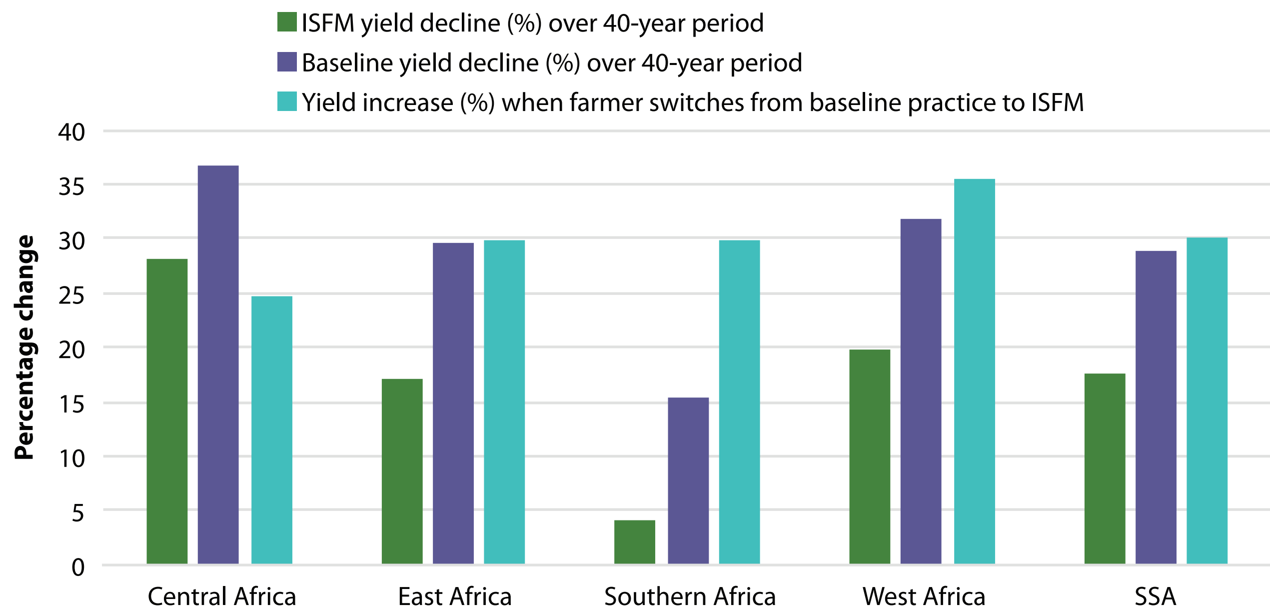
In an effort to better understand strategies for increasing the adoption of CSA, it is important to examine the objectives of CSA and the incentives for its adoption. To set the background for this analysis, this section illustrates the CSA objectives by using empirical evidence to show how ISFM, as an example of CSA, achieves these objectives.

Objective 1: Sustainably Increase Agricultural Productivity

Long-term soil fertility trials in Kenya have shown that the yield and soil organic carbon (SOC) of plots treated with ISFM, fertilizer only, and organic inputs decline over time (Figure 8.1 and Table 8.1). In the 21-year period reported (1972-1993), maize yield and SOC for the plots that did not receive any external inputs fell by almost 80 percent and 40 percent, respectively, whereas the yield on ISFM plots fell by only 34 percent (Figure 8.1). The percentage yield decline for the plots receiving inorganic fertilizer and those receiving organic inputs only were comparable to that of the ISFM plots. In fact, the average yield of plots under organic inputs was 23 percent higher than that of plots under fertilizer only. This result underscores the potential negative impacts of policies that promote fertilizer only. During the 1990–1993 period, findings suggest that yield increased threefold, from 0.9 tons/ha[43] to about 3.0 tons/ha (Table 8.1), when farmers switched from no external inputs to ISFM.

The decline in yield is largely due to continuous cropping, which depletes SOC and leads to deterioration of soil chemical and physical properties (Nandwa and Bekunda 1998). A subregional-level analysis using 40-year crop simulation modeling (Nkonya et al. 2017) shows comparable results—though smaller in impact, largely due to extensive aggregation (Figure 8.2). Yield on plots treated with ISFM fell by 18 percent, compared with about 30 percent for the baseline treatment, which is the average soil fertility management practice in SSA and differs across countries (Figure 8.2). If maize farmers in SSA adopt ISFM, food security will increase by at least 30 percent for the 50 percent of the SSA population who are maize consumers (CIMMYT 2016) (Table 8.2). This means that ISFM and other CSAs will improve food security, even though the improvement will happen at a declining rate if farmers practice continuous cropping.

FIGURE 8.2—YIELD CHANGE DUE TO LONG-TERM CONTINUOUS MAIZE CROPPING UNDER INTEGRATED SOIL FERTILITY MANAGEMENT AND OTHER LAND MANAGEMENT PRACTICES, 1980–2010



Source: Results of Decision Support System for Agrotechnology Transfer (DSSAT) crop simulation model from Nkonya et al. (2016) study.
Note: Baseline is average soil fertility management practice in SSA and differs across countries. ISFM = integrated soil fertility management; SSA = Africa south of the Sahara.

On-farm experiments in SSA have shown that a combination of CSA practices can sustainably increase agricultural productivity. Increased productivity can also be sustainable if farmers use a combination of other CSA practices that can help maintain and restore soil fertility. Such practices include fallowing, agroforestry, crop rotation, reduced tillage, cover crops, and balanced fertilizer application (Tilman et al. 2002). For example, a

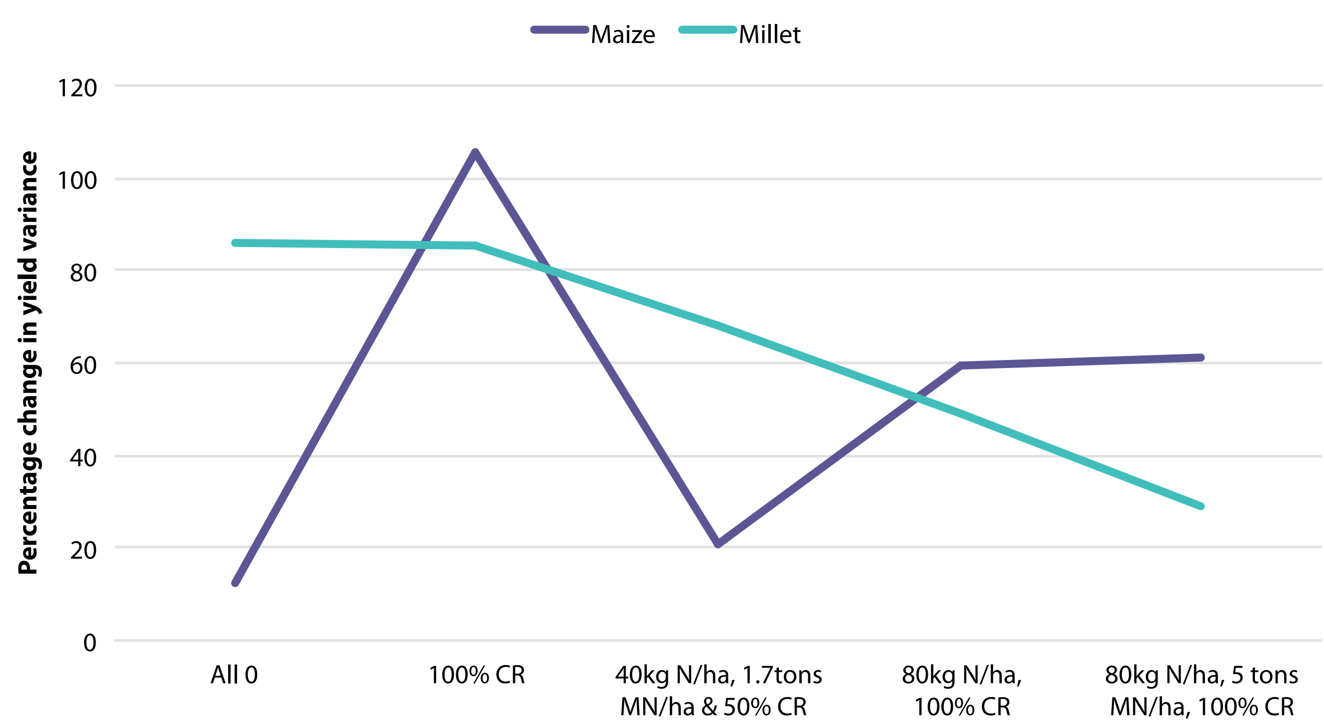
43 Throughout the chapter, *tons* refers to metric tons.

long-term (10-year) agroforestry experiment in Malawi showed that the yield of maize intercropped with Gliricidia started to increase in the third year and ultimately reached about 500 percent of its year-one yield (Akinnifesi et al. 2010). Gliricidia also improved SOC and other chemical and biophysical characteristics (Akinnifesi et al. 2010). In summary, the first CSA objective, of sustainably increasing agricultural productivity, can be achieved using a combination of practices that are affordable to smallholder farmers in SSA.

Objective 2: Increase Adaptation to Climate Change

ISFM practices reduce yield variability by improving the soil's water-holding capacity (Gentile et al. 2008; Lal 2011; Govaerts et al. 2009; Manna et al. 2005). To illustrate, Figure 8.3 offers results of a 30-year crop simulation, showing a declining yield variance for maize and millet as soil fertility management improves in Mali.[44] These results underscore the adaptation potential of ISFM and other CSA practices that enhance SOC.

FIGURE 8.3—IMPACT OF SOIL AND WATER MANAGEMENT ON MAIZE AND MILLET YIELD VARIANCE, 30-YEAR DSSAT SIMULATION RESULTS, MALI



Source: Results of DSSAT crop simulation model from Nkonya, Koo and Kato (2017).
Note: CR = crop residues; MN = manure; DSSAT = Decision Support System for Agrotechnology Transfer; tons = metric tons.

Objective 3: Mitigate Climate Change

As seen above, ISFM significantly increases SOC, simultaneously contributing to adaptation and mitigation of climate change. However, climate change mitigation may not be a criterion used by farmers to make investment decisions. Thus, there is a need to incentivize farmers to adopt ISFM in the form of payment for ecosystem services (PES). Determining the level of off-site climate mitigation benefits that accrue from ISFM would help policy makers design strategies for incentivizing adoption

44 Our own simulation results, not reported here, show there was an increase in yield variability due to climate change.

of ISFM and other CSA practices. We use crop simulation results from Rwanda to compute the value of the climate mitigation services provided by ISFM. A large proportion of Rwandan farmers (about 40 percent) use no external inputs (Nkonya et al. 2017), so that practice becomes our baseline. Farmers who adopt ISFM sequester more carbon (as CO_2 equivalent) than those using the baseline practice. The additional CO_2 equivalent sequestered is worth close to US$3,000/ha, which is about 200 percent of the profit these ISFM farmers get from their maize grain harvest (Table 8.2).

The discussion above shows that ISFM achieves all three major objectives of CSA, yet its adoption is the lowest among land management practices in SSA. Below we discuss the adoption pattern of ISFM in relation to its profitability.

Adoption of ISFM and Other Soil Fertility Management Practices

The adoption rates of ISFM and other soil fertility management practices differ significantly across crops. In Kenya, adoption of ISFM is highest for potatoes and beans, both of which are commercial crops (Figure 8.4). In Zambia, ISFM adoption is highest on maize plots and lowest on soybeans (Figure 8.5), an expected outcome, given that maize is Zambia's staple food crop, accounting

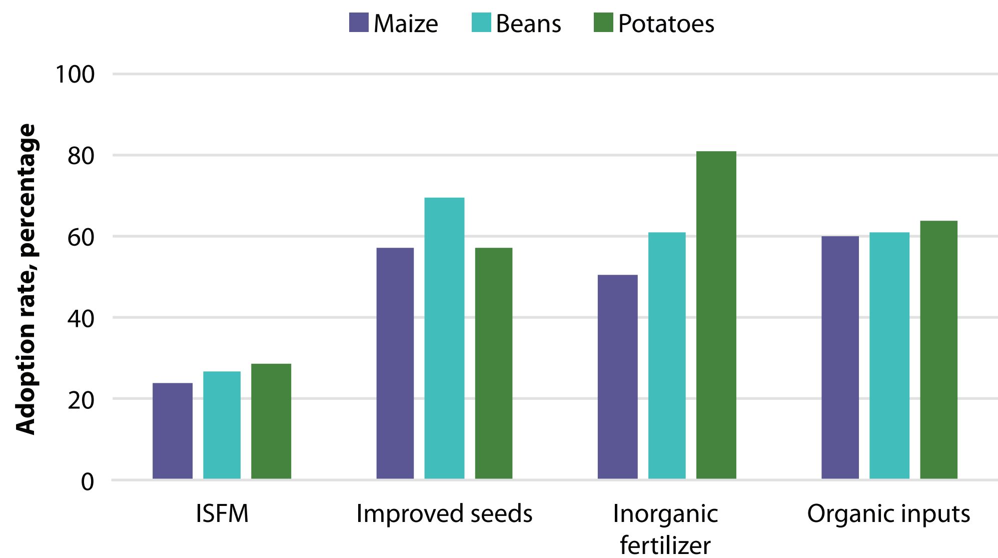
TABLE 8.2—VALUE OF OFF-FARM BENEFITS (CLIMATE MITIGATION) OF ADOPTING INTEGRATED SOIL FERTILITY MANAGEMENT ON MAIZE PLOTS

Statistic	Treatment			
	ISFM	Fertilizer	Organic	Baseline[b]
Yield (metric tons/ha)	3	2	2	1
Cost of production (US$/ha)	127	175	62	51
Profit (US$/ha)[a]	1,350	855	891	654
Value of CO_2 equivalent sequestered—net of value sequestered with no external inputs[c]				
• CO_2-equiv. sequestered (US$/ha)	2,701	584	1,095	n.a.
• As percentage of total profit	200	68	123	n.a.
• Off-farm benefit as % of total benefits	67	41	55	n.a.

Source: Computed from Nkonya et al. (2017).

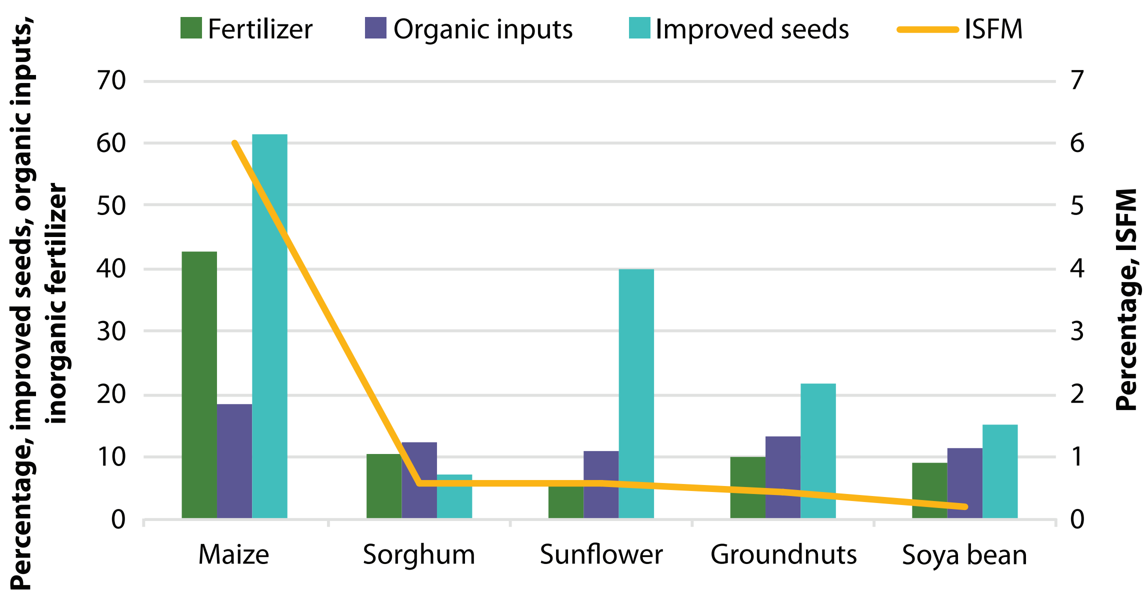
Note: [a] Price of maize per ton = US$475 (RATIN 2017). [b] Baseline is no external inputs. [c] Carbon price varies widely, from as low as <US$1 to as high as US$126 per ton of CO2 equivalent (World Bank 2017). n.a. = not applicable.

FIGURE 8.4—ADOPTION RATE OF IMPROVED SEEDS AND SOIL FERTILITY MANAGEMENT PRACTICES, KENYA, 2015



Source: Nkonya et al. (2017).

FIGURE 8.5—ADOPTION RATE OF INTEGRATED SOIL FERTILITY MANAGEMENT, ZAMBIA



Sources: Calculated from Rural Agricultural Livelihoods Survey (RALS) survey 2012 raw data.

for 49.4 percent of the country's caloric intake (FAO 2013). As is common in other countries, ISFM has the lowest adoption in Kenya and Zambia among the four technologies considered—improved seeds, inorganic fertilizer only, organic inputs only, and ISFM (Figures 8.4 and 8.5). Adoption of improved seeds is higher in both countries than elsewhere in SSA. For example, adoption of improved maize seeds is 33 percent in eastern Africa and 38 percent in southern Africa (Scoones and Thompson 2011), compared with 57 percent in Kenya. Adoption of inorganic fertilizer for potatoes is especially high in Kenya, where the tuber crop is grown for commercial purposes. Interestingly, Kenya has much higher inorganic fertilizer adoption than Zambia even though the latter gives a generous fertilizer subsidy, reflecting the effect of Kenya's strong input markets and the presence of agroforestry supported by local and international institutions.

The Unholy Cross?

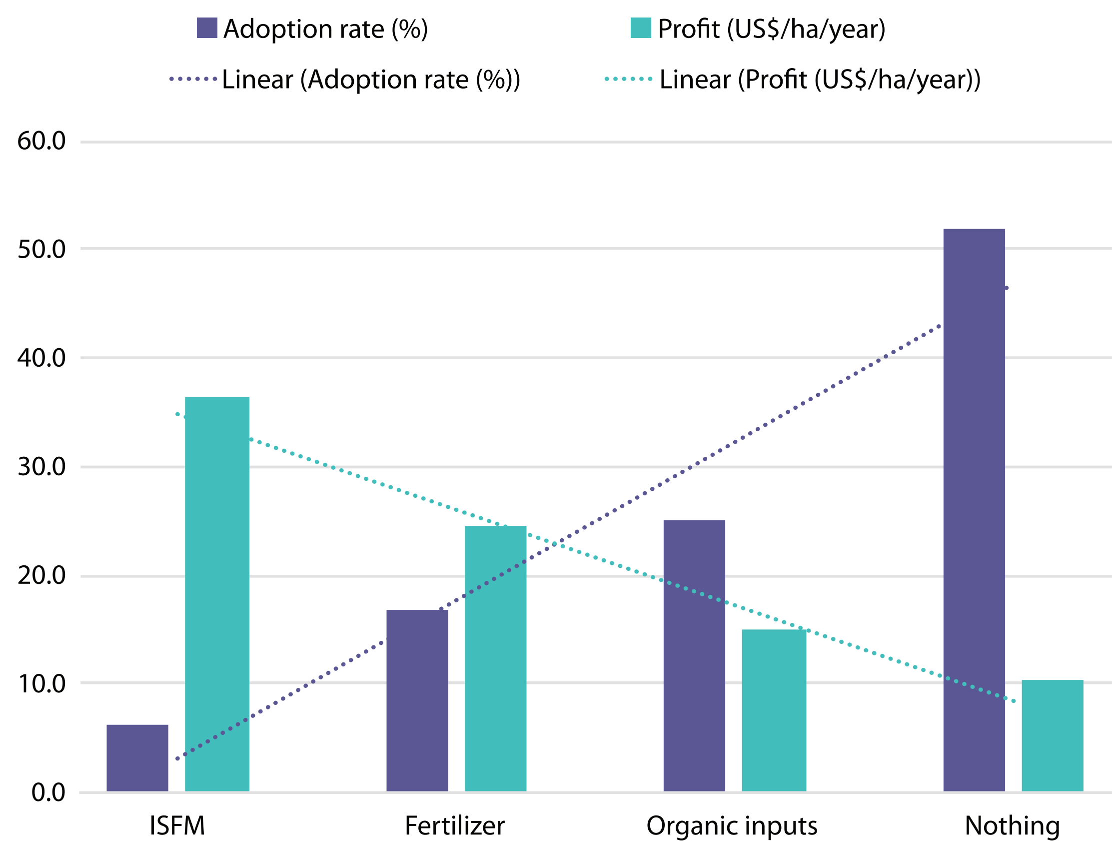
Our study to determine the profitability of fertilizer and other soil fertility management practices revealed puzzling results. According to economic theory, the higher the profit of a soil fertility management practice, the higher the adoption rate should be. However, our analysis of household survey data from seven SSA countries (Kenya, Malawi, Mali, Niger, Nigeria, Senegal, and Uganda) shows an inverse relationship between profitability and adoption of soil fertility management practices (Figure 8.6). ISFM has the highest profit but the lowest adoption rate. The majority of farmers (52 percent) apply no inputs at all, even though this practice has the lowest profit!

An important question is why we observe such puzzling farmer behavior. Below we discuss some possible reasons for the observed pattern based on our empirical studies and literature review.

Weak promotion of ISFM by extension agents: The first important question concerns the advisory services that farmers receive from extension service providers. Nkonya, Koo, and Kato (2017) asked extension agents in Nigeria and Uganda what types of extension messages they give to farmers.

Only one-third of the surveyed extension agents reported providing messages on organic soil fertility management practices—compared with about 70 percent who provided advisory services on inorganic fertilizer (Figure 8.7). In both countries, no extension agents reported promoting ISFM, suggesting weak capacity of extension agents to provide advisory services on ISFM. It is not surprising, then, that the adoption of ISFM in Nigeria and Uganda is only about 1 percent (Nkonya et al. 2016). The most common extension messages given were on improved varieties (about 90 percent of agents) and agrochemicals (about 80 percent). These are traditional messages that have been provided to farmers since the early 1960s to increase crop yield. The new paradigm of ISFM started in the late 1980s[45] (Bationo et al. 2007), so it is possible that many extension service providers have not received ISFM training. The majority of the extension agents interviewed were middle-aged, with an average age of 44 in both countries. Nkonya, Koo, and Kato (2017) conducted the extension agent study in 2012, so the agents' age suggests that they graduated from college in the 1980s or early 1990s, when ISFM was not yet widely known and the extension emphasis was on improved varieties and agrochemicals.

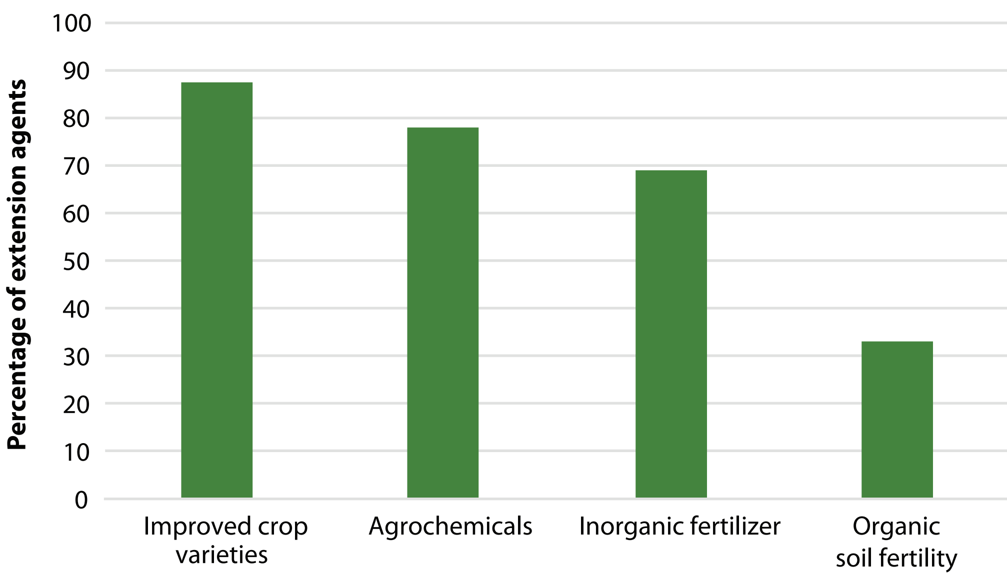
FIGURE 8.6—THE UNHOLY CROSS: INVERSE RELATIONSHIP BETWEEN PROFITABILITY AND ADOPTION OF SOIL FERTILITY MANAGEMENT PRACTICES, AFRICA SOUTH OF THE SAHARA



Source: Authors' calculations using raw household survey data from Kenya, Malawi, Mali, Niger, Nigeria, Senegal, and Uganda.

45 The first study documenting ISFM was published in 1987 (Kang et al. 1987).

FIGURE 8.7—TYPES OF MESSAGES GIVEN TO FARMERS BY EXTENSION AGENTS IN NIGERIA AND UGANDA



Source: Nkonya, Koo, and Kato (2017).

Labor intensiveness of ISFM involving biomass transfer: The majority of farmers who reported use of organic inputs applied manure. Our study has shown that labor accounts for 50 percent of the total cost of production for ISFM adopters who use manure or other organic inputs involving biomass transfer—that is, transportation of organic inputs from a source (such as the cattle pen) to crop plots.

The best strategy to address the high labor intensity of ISFM is to use agroforestry—that is, to incorporate trees on agricultural land. Studies have shown that planting leguminous trees on cropland can fix a large quantity of atmospheric nitrogen and carbon, both of which enhance soil fertility. For example, Sesbania sesban can fix up to 84 kg/ha of nitrogen (Akinnifesi et al. 2008), a level that supplies the recommended amount of nitrogen for maize, the leading consumer of fertilizer in SSA. Agroforestry labor is high only during planting, and no significant labor investment is required to maintain agroforestry trees.

High fertilizer cost: Fertilizer prices in SSA are much higher than in other countries; indeed, a kilogram of urea in SSA costs about US$1,[46] compared with US$0.65 in the United States (USDA 2016). The high fertilizer price in SSA is a result of high transportation costs, and it translates into high input transaction costs and lower profit for farmers. Most farmers also use unimproved varieties, whose yield response to fertilizer is low. All these factors translate to low fertilizer demand.

Off-farm and long-term nature of ISFM benefits: As seen above, a large share of the total benefits of adoption of ISFM is off-farm. Farmers are not likely to take into account off-farm climate mitigation services when making soil fertility improvement decisions. In addition, smallholder farmers also heavily discount investments in practices whose benefits are attainable only in the long run (Van Campenhout, D'Exelle, and Lecoutere 2015), a preference that further reduces the probability that they will adopt carbon-sequestering practices.

Profitability of no-input farming with no up-front investment: Though the "doing nothing" option has the lowest profitability, it is profitable, has no up-front investment costs, and is less risky than other practices.

46 This calculation is based on district-level fertilizer price data available from MIPAD (2017).

This could be the reason that the majority of farmers prefer this option. Meijer and others (2015) also observed that risk-averse smallholder farmers invest in low-cost management practices.

What Could Be Done to Undo the Unholy Cross?

A number of factors need to be considered to address the challenges discussed above.

Re-education Programs for Extension Agents

The capacity of extension agents to provide advisory services on ISFM, organic soil fertility, and other new paradigms for sustainable soil fertility management is low. There is a need to increase this capacity by providing short-term training and workshops to extension agents who are already in service. Such training could be provided by researchers, nongovernmental organizations, and other scientists with good knowledge of the new sustainable soil fertility management practices. This new knowledge must also be incorporated in agricultural college curricula to ensure that new graduates are equipped to promote new sustainable practices.

New Policies and Strategies that Do Not Treat Smallholder Farmers as Subsistence Farmers

For too long, government and even donor policies and strategies have treated smallholder farmers as subsistence farmers. Consequently, they have largely focused on provision of production-oriented rural services. For example, public extension agents affiliated with the ministries of agriculture largely provide production-related advisory services, whereas, in most countries, marketing advisory services are relegated to the ministries of industries and trade, where they do not receive much attention. Fertilizer can be profitable if it is applied to improved varieties that respond well to it. This means smallholder fertilizer users need to be treated the same as commercially oriented farmers and given appropriate advisory and other rural services. Smallholders face the same market forces that large-scale farmers do. For example, for them to adopt ISFM, they need to buy improved seeds and inorganic fertilizer—thus elevating their farming to market-oriented economic activity. At the same time, their higher output will require selling at remunerative prices. Hence, the provision of marketing advisory services should be incorporated into strategies to increase the capacity of extension services.

Storage Facilities and Other Market Value Chain Investments

As pointed out above, fertilizer is still quite expensive; therefore, its adoption will depend on farmers' perception of risk. This situation calls for the implementation of risk-coping mechanisms, including ISFM; improved seeds; storage facilities; processing equipment; and enhanced access to markets, crop insurance, and so on. For example, in the Democratic Republic of the Congo (DRC), farmers do not use fertilizer on maize because they often leave maize to dry in the field until a buyer shows up. With fertilizer, the maize husks are too heavy and tend to break the stalk, which may lead to loss of the harvest while waiting for a buyer. In this case, increased postharvest storage capacity could allow farmers to use fertilizer without the fear of crop loss. It could also enhance market participation, allowing farmers to delay sales, which could translate to higher prices.

Payment for Ecosystem Services

Given that a large share of the benefits of ISFM and other CSA practices are off-farm, subsidized programs could be used to incentivize farmers to adopt CSA practices. Subsidies could be given on the condition that a farmer adopt an easily verifiable land and water management practice that sequesters significant soil carbon. Promoted practices could include agroforestry, soil and water management structures, and others. The subsidies could be turned into PES to attract both national and international buyers. Needless to say, a strong market and verification strategies need to be developed to overcome a host of problems facing PES in developing countries, such as land tenure, legal knowledge of operating under contracts, and the like.

Concluding Remarks

CSA practices have both on-farm and off-farm benefits that far outweigh their investment costs. Yet their adoption rates are low in SSA. Increasing CSA adoption rates will require increasing the capacity of extension agents to provide the required advisory services. Additionally, CSA adoption requires significant farmer market participation to buy inputs and sell outputs. Unfortunately, current policies and investments remain focused on production, and efforts to improve the food value chain are limited. This situation will need to change to support widespread CSA adoption. To increase incentives for CSA adoption, it is important to design policies and strategies for PES because as much as two-thirds of the total benefit of ISMF is off-farm. Current subsidy programs can easily be turned into PES. Such a strategy will simultaneously serve food security and climate change adaptation and mitigation objectives.