The Business Case for Resilient Agriculture:

A financial and risk analysis of maize farming technologies in Kenya

Context

Maize-mixed farming is the most important food production system in East and Southern Africa, stretching over 19% of the cultivated area and engaging approximately 60 million people [1]. In Kenya, maize (*Zea mays* L.) is the main staple of 96% of the population and is cultivated by more than a third (38%) of the farmers [2]. Roughly 70% of production is small-scale (0.1-2 hectares [ha]) [3]. Maize areas cover approximately 1.8 million ha, from the coast lowlands (1-1250 meters above the sea level [masl]) to high potential highlands (>2100 masl), including eight provinces: Rift Valley (with the largest area under maize), Nyanza, Eastern, Western, Coast, Central, North Eastern, and Nairobi.

Maize harvests have stagnated between 1.5 and 2 tons/ha since the 1980s, while acreage has increased by almost 40% between 1992 and 2012, expanding mainly to marginal areas with low, unreliable rainfall [4]. This has had major implications for food security and rural livelihoods. Undernourishment and under-five stunting rates are at 24% and 26%, respectively. Many households, especially in the west, are food secure for a maximum of no more than eight months per year. With accelerated population growth (over 2.5% annually) [5], cereal demand (especially for maize) has surpassed domestic production; the production gap is expected to widen and reach 5 million metric tons by 2050 [6].

Crop yields are constrained by unreliable and unpredictable rainfall, low soil fertility and land degradation (soil fertility loss, erosion, degradation, deforestation, and desertification), pests and diseases (*Striga*, stem borer, etc.), and low uptake of sustainable practices [4]. Farmers typically cultivate maize repeatedly, with minimal or no fallow and low use of external inputs due to low availability and high costs. Every year, land degradation causes losses of about US$ 270 million, the equivalent of 1% of the country's Gross Domestic Product (GDP) or $117/ha annually, affecting the livelihoods of 12 million people[1] [7].

There is a critical need for investing in improved soil fertility and crop productivity. This brief unpacks critical information on the benefits, costs and risks associated with different agricultural management options that are common to the maize-mixed system in Kenya, from a smallholder farmer's perspective. It allows investors at different levels to anticipate the profitability, riskiness and societal value of investments for enhanced soil fertility and livelihoods and so allocate resources effectively.

The information in this brief is based on a compilation of peer-reviewed scientific studies examining the difference in performance of conventional and improved agricultural technologies, known as "Evidence for Resilient Agriculture" (ERA). ERA specifically collected data on the effects on productivity, resilience and greenhouse gas emissions in farming systems [8]. Economic performance, risks and rewards were among the indicators compiled in that effort. The objective of this brief and its companions for other countries is to set the baseline for the business case for resilient agriculture and therefore, directly respond to the need for more information about the economics of agricultural technologies.

More than 1,400 studies included in ERA were conducted across Africa. One hundred and sixty-one peer-reviewed studies included in ERA took place on a farm or research station in the country's key agro-ecological zones (AEZs) and published between 1970 and 2014. Of these, 41 captured farm budgets for different production systems (cereals, vegetables, livestock, fish, etc.). This brief reports data from financial assessments from 27 studies that offer information on variable costs, gross margins and gross returns and yield risks for maize-based systems in Kenya.

[1] The estimation is based on soil nutrient loss decreasing yields of main crops – maize, wheat and rice.

Soil nutrient depletion and incidence of pests occur across all major agroecological zones and affect food security and incomes. Various sole or integrated soil fertility and pest management interventions are known to address these challenges, but are they financially viable for small-scale farmers?

On average, **soil management techniques** can bring economic gains of up to almost 500% compared to farmer conventional practice (Table 1). Green manure with *Desmodium uncinatum* has been found to effectively suppress *Striga* and fix nitrogen, increasing yields and revenues [9]. On the other hand, despite good productivity outcomes, use of *Crotala*ria is less profitable as it does not produce a marketable output, decreasing gross margins by more than 100% [10]. In sub-humid environments, reduced tillage alone or in combination with legume mulch does not produce the same effects even after ten seasons of application, reducing margins by 15-18%. This is largely linked with low maize productivity under reduced tillage, as a result of surface runoff, nutrient loss and reduced water infiltration in soils. Moreover, savings in labor is not sufficient to compensate for the low yields and income obtained [11]. This suggests that conservation tillage, while being an opportunity to slow or reverse land degradation, may not always be economically attractive to farmers, explaining lagging adoption rates of the practice throughout the country.

Agroforestry practices (the use of trees on farms), sole or in combination with nutrient management techniques) also show positive economic impacts on farm income. Combinations of *Tithonia diversifolia*, *Leucaena leucocephala* and *Calliandra calothyrsus* with mineral fertilizer (diammonium phosphate [DAP] triple superphosphate [TSP] broadcasting and TSP application, among others) enables farmers to generate positive gross margins of up to 184% more than business as usual (BAU). Even if the variable costs increase (particularly for labor required for cutting, transportation and incorporation of prunings into soil), most agroforestry systems still become profitable, as they result in high returns to labor compared with the opportunity cost of labor. Use of family labor is very common, the smallholder family providing up to 20 times more labor than hired workers [3]. Low and negative margins are typically associated with low yields and hence low returns, especially in semi-arid environments, where trees and shrubs compete for water resources with maize.

Spatial diversification (**intercropping**) can increase gross returns and margins by up to 134% and 353% respectively compared to BAU, especially when using forage legumes (*Desmodium*) [9]. Temporal diversification (maize-cowpea, maize-soybean **rotations**) is also likely to bring economic gains despite costs for seed, starter fertilizer and labor, among others [10]. Results for crop rotations are also highly variable and depend on numerous factors; for instance, cowpea incurred almost 20% higher costs than soybean, mostly because of frequent and greater infestation by insect pests [12]; rotations with Lucerne, sesame, peanut, sunflower, pigeon pea and maize in different combinations and at different times can increase average returns by to 340% compared to BAU [13]; soybean rotations were profitable with local maize varieties but registered negative margins when used with an improved maize variety known to be effective in pest control [10].

Overall, **nutrient management** practices may pay off, increasing margins by up to 1350%. Yet results from trials included in this brief vary across practices. Fertilizer generally increased maize yields to the extent to justify the relatively higher costs of fertilizer and labor (compared to BAU). However, previous research stressed out that the recommended application rate is much higher than smallscale farmers in Kenya can afford, indicating that most farmers may not have the capacity to pay the upfront fertilizer costs to begin with [10]. Margins may be negative when mineral fertilizer is used in combination with other soil management practices (e.g., mulch), most likely due to the additional labor required and limited increase in crop yields.

Table 1 Average economic performance of selected agricultural technologies for maize, based on data from 27 peer-reviewed publications (for a full list, see https://era.ccafs.cgiar.org/query/app/). Values for "Improved practice" are expressed in USD/ha. "Percent change" refers to change from farmer (conventional) practice. Reported economic data was standardized to 2010 values to ensure comparability across studies.

	VARIABLE COSTS		GROSS RETURNS		GROSS MARGINS	
	Improved practice	Percent change	Improved practice	Percent change	Improved practice	Percent change
AGROFORESTRY (ALL)	3,713	29%	1,172	26%	364	58%
Agroforestry Pruning	6,318	55%	2,008	10%	352	10%
Agroforestry Pruning-Alleycropping	3,760	5%	1	0%	385	-19%
Agroforestry Pruning-Inorganic Fertilizer	1,061	27%	1,507	68%	356	184%
CROP MANAGEMENT (ALL)	2,568	12%	673	149%	221	210%
Crop Rotation	3,328	1%	703	165%	139	68%
Intercropping	1,808	24%	643	134%	302	353%
NUTRIENT MANAGEMENT (ALL)	506	73%	1,081	65%	534	337%
Inorganic Fertilizer	715	82%	1,341	126%	845	1350%
Organic Fertilizer	585	134%	1,193	100%	596	107%
Inorganic Fertilizer-Organic Fertilizer	385	283%	1,671	291%	696	906%
Inorganic Fertilizer-Mulch	468	3%	1,044	0%	575	-3%
Inorganic Fertilizer-Mulch-Reduced Tillage	487	-12%	1,087	-13%	598	-14%
Inorganic Fertilizer-Reduced Tillage	513	-11%	977	-11%	462	-10%
Green Manure-Inorganic Fertilizer	385	30%	258	-37%	-35	26%
SOIL MANAGEMENT (ALL)	448	232%	945	34%	551	132%
Mulch	123	934%	873	67%	427	109%
Mulch-Reduced Tillage	355	-10%	842	-13%	487	-15%
Reduced Tillage	450	-13%	982	-15%	507	-18%
Green Manure	866	15%	1,222	54%	1,248	485%
Crop Residue Incorporation	No data	No data	807	75%	87	96%

Variable and uncertain biophysical, economic, and policy environments make farming a risky enterprise, stymieing technology adoption. Can some investments reduce risks and still bring profits to smallscale farmers in Kenya?

Kenyan farmers directly contribute a quarter (25%) to national GDP. Smallholders, estimated at 16 million in 2015, produce almost two-thirds (63%) of the total food in the country [3]. Uncertain weather and climate, harsh environmental conditions, incidence of pests and diseases, volatile prices, inadequate marketing infrastructure and financial constraints disrupt agricultural production and influence farmers' ability to generate income and profits and to contribute to food security. Production risks—manifested though unreliable yields due to droughts and floods, pests and diseases, among others—have direct and immediate effects on farmers livelihoods, via fluctuations in income. Production risks can also affect the national economy, as agriculture and the country's GDP growth are strongly correlated. Crop losses registered between 1980 and 2012 have decreased GDP by at least 2% every year, 20% of which have been associated with maize yield losses [4].

Between 1992 and 2012 maize yields have been highly variable. Almost 20% of the maize production takes place in areas with high rainfall variability, where farmers register yield below the national average (1.08 t/ha compared to ~1.62 t/ha) [4]. Ninety-eight percent of Kenya's agriculture is rainfed, which makes it highly susceptible to increasing temperatures, droughts, and floods. Climate change projections indicate potential rainfall increases concentrated in some regions (Lake Victoria to central highlands), while dry areas (eastern and northern arid and semiarid-lands) would become even drier, with longer and more frequent dry periods [14]. By 2050, losses from expected maize yields are estimated at US$100–200 million annually by 2050 [15] while food prices are expected to increase between 75-90% [16].

With limited resources, smallholder farmers are typically risk averse, usually preferring low- return investments over more profitable yet uncertain options. Such decisions usually lead to limited/zero farm investments and low capital accumulation.

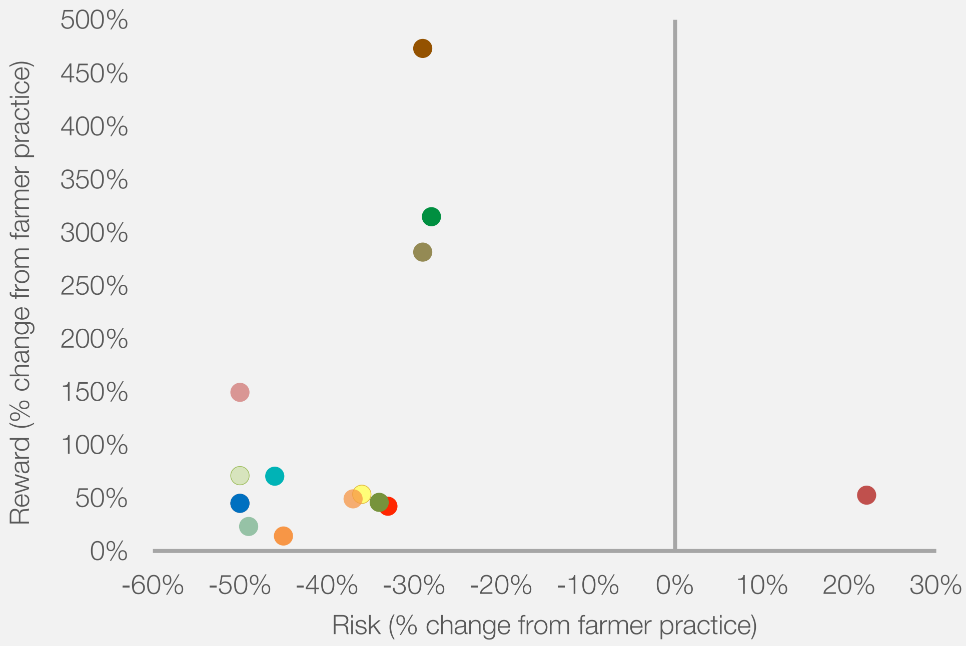
Our analysis shows that most practices analyzed in the brief not only reduce production risks by up to 50% but they also increase profitability for farmers by more than 400% compared to BAU (Figure 1). Since households' food insecurity is largely determined by economic poverty—which makes people more susceptible to shocks—there is a big opportunity to invest in practices with potential to lift the farmers' economic conditions and eliminate production risks.

Diversification is often cited as one of the most effective, at hand strategy to reduce risks and rightfully so. Intercropped systems and crop rotations are long-established methods to minimize risk of total crop failure, especially on low-capital farms. However, our findings also show that the economic benefits of rotations highly depend on the crops and varieties used, fertilizer needs and costs, and the biophysical conditions, among others (Table 1). In general, risks are lower when low-risk crops (productive and marketable) are included.

As Table 1 shows, trees on farms can be a lifebelt for many Kenyan farmers, while ensuring a variety of environmental services such as improving soil fertility, protecting crops and livestock from wind, restoring degraded lands, limiting pests and preventing soil erosion, etc. There are hundreds of trees, shrubs and vines with agroforestry applications but no on-size fits all solution. In areas with poor soils and inadequate replenishment of plant nutrients, the combination of crops, trees and mineral fertilizer has more potential to decrease maize production risks compared to sole maize planting or maize fertilized with tree prunings; however, rewards are not as attractive, due to the high price of fertilizer and tree seeds. Matching the right species and management practices to local conditions is critical for optimal resource use (water, land, light) and for obtaining positive outcomes [17].

Nutrient management technologies produce mixed results, with maize under a combination of reduced tillage, mulch and inorganic fertilizer, being riskier compared to maize under conventional tillage practices and no fertilizer, but still viable from an economic point of view. Such trade-offs between production/food security and income/resilience outcomes are not exceptional, but characteristic to farm landscapes. Generating and sharing knowledge about the performance of management options can help farmers take more informed, context-tailored decisions.

Figure 1 Risks and rewards associated with select agricultural technologies in Kenya. Risk analysis considered crop yields and minimum and average acceptable values for smallholder farmers. Risks are expressed as the possibility of yielding lower than the mean control value (0.5). Negative values indicate a lower risk to farmers compared to BAU. Rewards are expressed as benefit-cost ratio (BCR) ratio. Positive BCR indicates economic benefits for farmers.



	Risk (%)	Reward (%)
Agroforestry Pruning	-28	315
Agroforestry Pruning-Inorganic Fertilizer	-46	70
Crop Rotation	-29	473
Intercropping	-29	281
Inorganic Fertilizer	-36	53
Organic Fertilizer	-37	49
Inorganic Fertilizer-Organic Fertilizer	-49	23
Inorganic Fertilizer-Mulch	-50	45
Inorganic Fertilizer-Reduced Tillage	-50	45
Inorganic Fertilizer-Mulch-Reduced Tillage	22	53
Green Manure-Inorganic Fertilizer	-50	149
Mulch	-45	14
Mulch-Reduced Tillage	-33	42
Reduced Tillage	-34	46
Green Manure	-50	71

PERSPECTIVES

Our metanalysis identified 27 studies that investigate the economic benefits, costs and risks of key agricultural management options for maize-based systems in Kenya. Additional analyses can target other crop and livestock systems, to shed light on investment opportunities for the country's agriculture sector. Since maize is a major staple of the population, we explored the potential of agroforestry, soil management, nutrient management and crop diversification investments to increase profits and to contribute to improved livelihood outcomes. Many promising technologies were not covered in this brief, due to lack of consistent data on economic outcomes (costs, returns, margins) and risks (yields). Farm budgets are hardly systematized and are not always compiled in the same way. This opens significant opportunity for extension agents (public, private, donors) to work directly with farmers and supply chain actors, building basic skills on preparing farm budgets and assessing cash flows, so that financial viability can be adequately documented and reported.

In most instances, results from our analysis are compelling. Many resilient agricultural technologies have the potential to increase income and reduce risks for many farming households, at least over the medium and long term. Yet for many subsistence, resource-poor farmers, who expect immediate benefits from their business, even the low end is likely prohibitive especially when combining with all of the other factors that restrict adoption of climate-resilient technologies (Figure 2). The different types of risks experienced directly or indirectly by a farmer—production, marketing, finances, or policy—require multi-layered approaches to risk management, which should occur at different stages and in different forms. Such approaches may include, among others: access to practical knowledge about technologies, to timely weather and market information, to financial products (insurance, credit, microfinance) that allow them to effectively transfer some of the risks; and alliances between public, private, research (agronomists and economists) and farmers to close information loopholes and scale viable investments.

Figure 2 Selected barriers to adoption of climate-resilient technologies, as identified in the studies included in the brief.

- Use of organic inputs largely depends on availability of plant material and labor. In Kenya, Tithonia is a favored bush tree, as it is a low-cost resource, growing along the roadsides. Yet it requires additional labor for fetching and incorporating it into soil. Moreover, it is freely available but increasingly scarce, as demand for it is growing [18].
- Green manure and crop residue incorporation produces positive effects on soil organic content if applied consistently and in sufficient quantities, which may turn impractical for smallholder farmers, who may use crop residue for other competing purposes (cooking fuel, livestock feed, etc.). Experiments with Tithonia showed that application of 1.82 t ha^{-1} did not increase availability of phosphorus, as a would have a rate of 5 t ha^{-1} [19].
- Soil quality is a limiting factor for the establishment and performance of practices like intercropping with annual legumes. Land degradation affects 17 to 30% of Kenya's cropland.
- Legumes can be detrimental to crop yields, depending on variety, management practice, time and agroecological zone (e.g., medium duration varieties and close-spaced planting of pigeon pea, lablab, or Mucuna can suppress maize yields).
- Inadequate policies may obstruct further investments in climate-resilient technologies. Maize imports at low prices have set standards against which smallholder farmers in Kenya cannot compete, contributing to slow technology adoption by farmers.
- In the absence of adequate marketing opportunities (means of transportation, access to formal markets, fair prices), many farmers are skeptical about planting additional legumes or even selling the crop harvest. In Kenya, smallholders sell less than a quarter of their production, retaining most of it for in-household consumption, which often means less revenues and less diversified diets.

Citations

[1] Adamtey et al. 2016. Productivity, profitability and partial nutrient balance in maize-based conventional and organic farming systems in Kenya. Agric. Ecosyst. Environ, 235, pp. 61–79.
[2] GoK. 2008. Annual Agricultural Statistical Bulletin. Government of Kenya
[3] FAO. 2015. The economic lives of smallholder farmers. An analysis based on household data from nine countries. Rome: FAO.
[4] D'Alessandro SP et al. 2015. Kenya - Agricultural risk assessment (English). Agriculture global practice note 17. Washington, D.C.: World Bank Group.
[5] Wiggins, S. (2018). Agricultural growth trends in Africa. Agricultural Policy Research in Africa (APRA) Working Paper 13, Future Agricultures Consortium.
[6] GoK. 2015. Economic Survey Annual Report. Government of Kenya
[7] Mulinge V et al. 2016. "Economics of Land Degradation and Improvement in Kenya – A Global Assessment for Sustainable Development," E. Nkonya, A. Mirzabaev, and J. von Braun, Eds. Springer International Publishing, pp. 471-498.
[8] Rosenstock TS et al. 2015. The scientific basis of climate-smart agriculture: A systematic review protocol Climate-Smart Agriculture Compendium. CCAFS Working Paper 138. Wageningen: CCAFS.
[9] Midega CA et al. 2013. Effects of mulching, N-fertilization and intercropping with Desmodium uncinatum on Striga hermonthica infestation in maize. *Crop Protection*, 44, pp. 44-49. doi: 10.1016/j.cropro.2012.10.018
[10] De Groote HK et al. 2013. Effectiveness of hermetic systems in controlling maize storage pests in Kenya. *Journal of Stored Products Research* 53, pp: 27-36. doi: 10.1016/j.jspr.2013.01.001
[11] Kihara J. et al. 2012. Effect of Reduced Tillage and Mineral Fertilizer Application on Maize and Soybean Productivity. *Experimental Agriculture* 48(2), pp. 159–75. doi: 10.1017/S0014479711000895.
[12] Rao MR and Mathuva MN. 2000. Legumes for improving maize yields and income in semi-arid Kenya. *Agric. Ecosyst. Environ* 78 (2), pp.123-137.
[13] Oswald AR et al. 2001. Striga control and improved farm productivity using crop rotation. *Crop Protection* 20(2), pp. 113-120. doi: 10.1016/s0261-2194(00)00063-6
[14] CIAT; WB. 2016. Climate-Smart Agriculture in Kenya. CSA Country Profiles for Africa Series. Cali: CIAT.
[15] Herrero M et al. 2010. Smart Investments in Sustainable Food Production: Revisiting Mixed Crop–Livestock Systems. *Science* 327, pp: 822–825.
[16] FICCF. 2013. A review of climate-smart agriculture initiatives in non-ASAL areas of Kenya. Nairobi, Kenya: Finance Innovation and Climate Change Fund (FICCF)
[17] Mbow C et al. 2014. Achieving mitigation and adaptation to climate change through sustainable agroforestry practices in Africa, Curr. Opin. Environ. Sustain 6, pp. 8–14.
[18] Onduru DD et al. 2008. Exploring options for integrated nutrient management in semi-arid tropics using farmer field schools: a case study in Mbeere District, eastern Kenya. *Int Journal of Agricultural Sustainability* 6(3), pp. 208-228. doi: 10.3763/ijas.2008.0267
[19] Opala PA et al. 2007. Effect of Phosphate Fertilizer Application Methods and Nitrogen Sources on Maize In Western Kenya: An Agronomic And Economic Evaluation. *Experimental Agriculture* 43(4), pp. 477–87. Doi: 10.1017/S0014479707005315

Acknowledgements

This document is part of the *Evidence for Resilient Agriculture Series Briefs* by the World Agroforestry (ICRAF). Development of The Business Case for Resilient Agriculture in Kenya was funded by the United States Department of Agriculture-Foreign Agricultural Service (USDA-FAS). It was implemented under the Partnership for Scaling Climate-Smart Agriculture (P4S) project that is co-led by ICRAF and the International Centre for Tropical Agriculture (CIAT) as part of the CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS). Contact: t.rosenstock@cgiar.org