The Business Case for Resilient Agriculture:

A financial and risk analysis of maize farming technologies in Malawi

Context

Maize-based farming systems are 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 Malawi, maize (*Zea mays* L.) is the main staple crop. It represents roughly 48% of the population's dietary energy consumption and occupies 80-85% of the total cultivated land [2]. Almost all farmers cultivate some maize. Maize areas cover all eight Agricultural Development Divisions (ADD), with Lilongwe and Kasungu containing nearly 50% of the country's area planted to maize.

Despite relative increases in average yields following the Farm Input Support Programme started by the Government in 2005, maize harvests remain below potential and highly susceptible to climate shocks. This has had major implications for food security and rural livelihoods. Undernourishment and under-five stunting rates are high, at 26% and 37%, respectively [3], while rural poverty incidence is at 60% [4]. Maize production is constrained by unreliable rainfall and frequent dry spells; degraded and infertile soils; limited area available for cropping, a diminishing farm labor force, and variable crop market prices, among others.

The need for investing in improved soil fertility and crop productivity is evident. This brief unpacks critical information on the benefits, costs and risks associated with different agricultural management options most common to the maize-based system in Malawi, from a smallholder farmer's perspective. This will help to anticipate the profitability and riskiness of resilient agriculture investments for enhanced soil fertility and livelihoods and so allocate resources towards technologies that provide the greatest value for money and returns for the farmer.

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 [5]. 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. However, Malawi is relatively understudied. Forty-five studies included in ERA took place on a farm or research station in the country's key agro-ecological zones (AEZs)—semi-arid, sub-humid and tropical highlands—and published between 1998 and 2013. The economic data available were derived from only seven studies. This brief reports data from financial assessments from this literature.

Evidence for Resilient Agriculture (ERA) Series

Continuous cropping coupled with low inputs of nutrients has mined already weathered and impoverished soils of the available nutrients, compromising yields and food security. Are there financially viable options to address these?

Evidence show that, on average, **soil management technologies** perform among the best of all major categories analyzed in this brief (Table 1). This is an effect of relatively small increases in variable costs (otherwise required for herbicide, sprayers and gear for weed control) compared to farmers' practice and significant growth in gross returns. At the same time, the return to labor more than doubles under a reduced tillage and mulch system compared to conventional tillage (±47 days per ha and ±65 days per ha, respectively), allowing farmers to save labor for growing other crops and women to participate more in market activities [6-8]. Relatively low increased costs combined with high relative returns generates the ability for farmers to generate gross margins of up to 50% more than business as usual (BAU).

Marginal benefits from combinations of practices (**reduced tillage, mulch and intercropping**) can be between 27 and 105% higher compared to BAU investments and even more economically attractive than individual soil management activities. These combinations were also reported to have up to three times higher net returns per hectare compared to conventional tillage systems (particularly in fourth and fifth seasons). This is likely due to increase in maize yields but also because part of the legumes harvested from the intercrop are sold on local markets [6-8].

Crop diversification is an economically viable option for maize smallholder farmers in Malawi [7, 9, 10, 11]. A comparison between spatial and temporal diversification suggests that **rotations** (temporal) increases gross returns and margins to a greater extent than intercropping (spatial). **Crop rotations** increased farmers' gross margin by up to 38% over BAU. The largest changes in gross returns (over 60%) was due to complex three species rotations (pigeon pea intercropped with peanut in year 1, rotated with maize in year 2) that favors more stable yields across the years [9]. Economic performance of **intercropping** is highly variable, with low negative values (as low as -23%) registered in maize-cowpea and maize-pigeon pea intercroppings (especially in years with high variable costs) and higher positive values (up to 55%) in maize-bean intercropping [7].

Data don't show the compensatory effect of increased revenues against higher variable costs for agroforestry. In theory, higher variable costs can be compensated for by increased revenues from maize and food legumes or tree products sales. In this case, however, where **alleycropping** with *Tephrosia vogelii* was trialed, gross margins decreased by 3% compared to BAU [9]. Rising variable costs (up to 37% over monocropping), mixed with relatively similar revenues meant that the gross margins of agroforestry can be negative. High costs for agroforestry are typically associated with increased labor effort for planting, hand weeding, pruning and harvesting the food/forage legume tree.

Increasing **nutrient inputs** by any mean typically increases the gross margin gained by the farmer. Inorganic fertilizers used in combination with organic materials (maize-bean intercrop) had the most significant effects, increasing gross margins to more than 200% relative to business as usual. That amount is a 3 to 4 times change over using inorganic nutrients along and can be attributed to the improved nutrient cycling and water soil moisture when organic materials are delivered to fields as well.

Where inorganic fertilizer was used in combination with an improved maize variety (MH 17), increased costs exceed the value of the returns and hence the gross margins declined [9]. This acts as a reminder of the riskiness of using inorganic fertilizer due to increased costs especially under uncertain weather conditions. Surprisingly, the data also suggest that **green manure**—particularly use of crops such as velvet bean (Mucuna)—, decreases gross margin as compared to farmer practices perhaps indicating a disincentive for use and adoption of this practice.

Table 1 Average economic performance of selected agricultural technologies in Malawi, based on data from seven peer-reviewed publications [6-12]. For a detailed 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 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)	72	37%	450	1%	377	-3%
Alleycropping (Tephrosia vogelii + Improved Maize Variety)	72	37%	450	1%	377	-3%
SOIL MANAGEMENT (ALL)	372	19%	1235	29%	634	47%
Intercropping (Maize/Bean)	318	15%	2499	13%	281	53%
Intercropping + Mulch (Maize-Cowpea; Maize-Pigeon pea)	509	10%	1217	3%	710	-1%
Crop Rotations (Maize/Groundnut; Maize/Groundnut/Pigeon pea)	100	84%	731	63%	631	38%
Mulch + Intercropping + Green Manure (Maize-Pigeon pea)	364	-12%	956	-1%	698	27%
Reduced Tillage + Mulch	439	6%	1069	39%	659	54%
Reduced Tillage + Mulch + Intercropping (Cowpea, Pigeon pea)	509	23%	1217	46%	762	57%
Reduced Tillage + Mulch + Intercropping + Green Manure	364	7%	956	40%	698	105%
NUTRIENT MANAGEMENT (ALL)	62	55%	472	49%	300	61%
Green Manure (Maize/Mucuna; Maize/Groundnut/Pigeon pea)	74	36%	490	-5%	416	-9%
Inorganic Fertilizer	35	35%	239	60%	274	56%
Inorganic Fertilizer + Intercropping (Maize-Bean)	35	No data	124	142%	159	210%
Inorganic Fertilizer + Improved Maize Varieties	105	94%	454	-1%	349	-14%

Farming is a risky business, subjected to a variable economic and biophysical environment. Are some investments less risky than others?

Uncertain weather and climate, pests and diseases, volatile prices, inadequate marketing infrastructure, financial constraints influence agricultural outcomes. Of all these, production risks are the most intuitive; they are manifested through unstable, unreliable yields and are intimately linked with droughts, pests and diseases. Production risks directly affect both the farm business—via fluctuations in income— and the national economy—as agriculture and the country's Gross Domestic Product (GDP) growth are strongly correlated. Annual economic losses linked to production risks amount to US$149 million, 30% of which are associated with maize yield losses [13].

Maize yields are already below potential and highly variable under existing climate conditions. Average yields range between 1.1 MT/ha (Shire Valley) and 2.7 MT/ha (Karonga and Kasungu), while coefficients of variation in yields range between 31% (Kasungu) and 48% (Blantyre) [13]. Projected temperature increases, rainfall variability throughout the country and more frequent floods and droughts are expected to constrain maize production, further deteriorating the poor food security situation of the population. Yields are expected to be reduced by up to 8 percentage points (pp) by 2030 and 10.6 pp by 2050 [14] and risks of pests and diseases are deemed to increase [15]

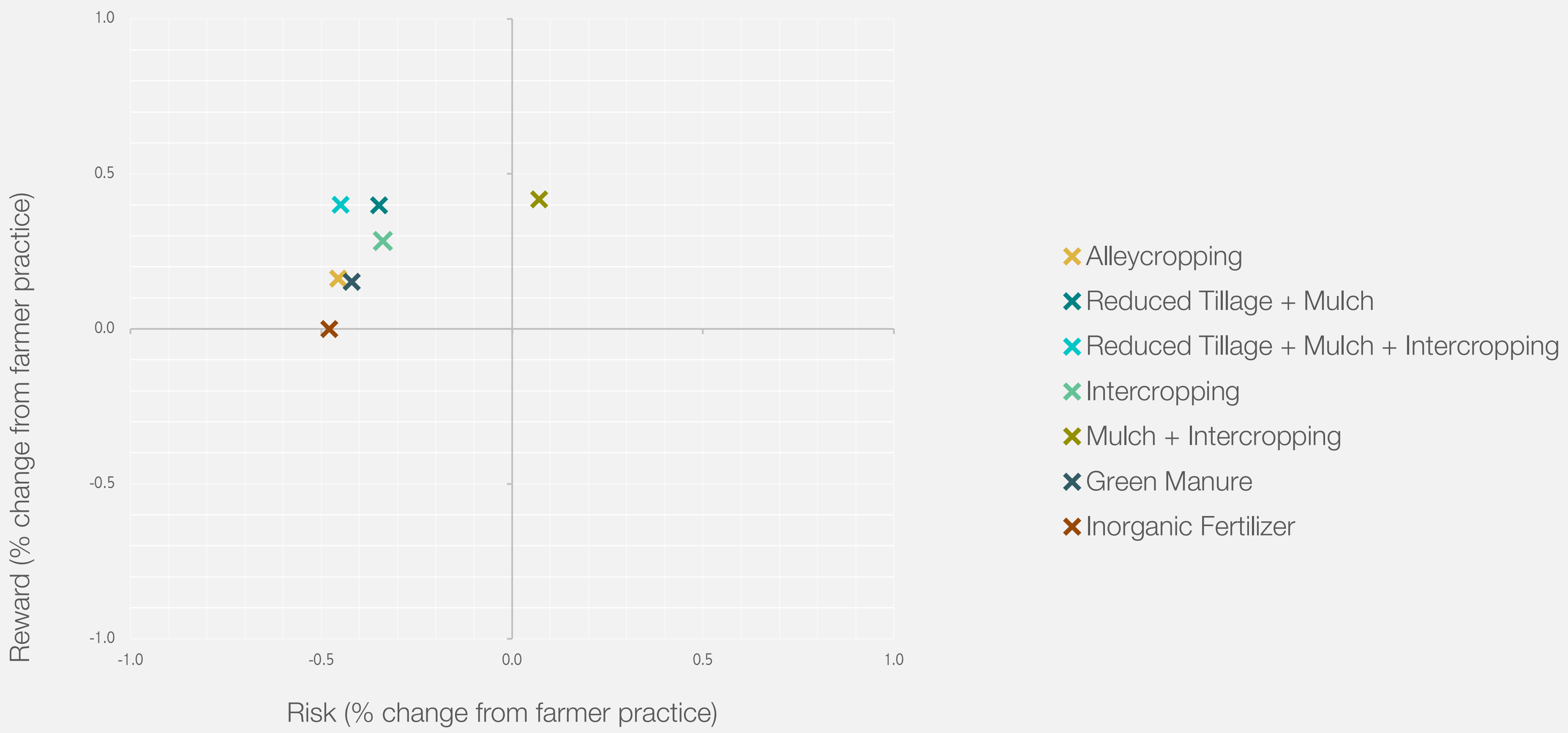
With limited resources and precarious livelihoods conditions, smallholder farmers are typically risk averse, usually preferring low-return investments over more profitable yet uncertain options. Such decisions usually lead to limited/zero farm investments and low capital accumulation. Yet the golden mean exists. 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 40% compared to BAU (Figure 1), indicating favorable conditions for farmers' adoption. Since households' food insecurity is largely determined by economic poverty [16]—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 are long-established methods to minimize risk of total crop failure, especially on low-capital farms. However, our findings also show that, when used in combination with mulch and conventional tillage practices, it increases the likelihood of obtaining yields below the minimum acceptable threshold (by up to 7%) while increasing revenues by up to 42% compared to BAU. Such trade-offs between production/food security and income/resilience outcomes are not exceptional, but characteristic to farm landscapes. Generating and sharing knowledge around the performance of different management options can help farmers take more informed decisions, suitable to their situation.

Farmers are exposed to and need to manage several other risks at a time, in addition to production. In Malawi, crop prices have been highly volatile over the years, in great part as a result of policy interventions that have distorted prices [13]. Prices of inputs and outputs have also been highly fluctuating mostly due to trade policies and shocks (e.g., droughts). Reports have also highlighted the unpredictability of transportation costs, as they are typically negotiated on an ad-hoc basis and farmers have little negotiating power to choose cost-effective markets access options. Situated at the heart of the supply chain, smallholder subsistence farmers are typically the most vulnerable to these types of risks due to their dependency on farming and lower capacity to adapt to sudden changes.

However, a riskier business does not necessarily mean it is unfeasible for smallholders. Understanding the risks, the vulnerabilities and underlying factors is an important entry point for designing optimal strategies to accept, avoid, eliminate/reduce or transfer risks. In most cases, production risks can be addressed directly by farmers, via changes in management practices. But support in ensuring access to adequate knowledge, information and financial products is critical. Price fluctuations linked with transportation and markets are largely in the hands of policy makers and traders. To effectively manage these different potential uncertainties that can affect the farming business, concerted action across the supply chain (producers, processors, traders, policy makers) and at all level (private, public) is required.

Figure 1 Risks and rewards associated with select agricultural technologies in Malawi. 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.



PERSPECTIVES

The prevailing narrative around resilient agriculture suggest there are few data to understand the business case for investment from the farmers' perspective. Our metanalysis identified only seven studies that investigate the economic benefits and costs of agricultural management options for maize in Malawi. This is only 20% of all the research captured by ERA for the crop in the country. Many promising technologies were not covered here, 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, encouraging the use and harmonization of farm budgeting methods, so that financial viability can be adequately documented and reported.

Regardless, these data show interesting trends in the required increases in costs (between 8 and 84%) to be able to implement resilient agricultural technologies. Given the low level of assets and resources available to many smallholders in Malawi, even the low end is likely prohibitive especially when combining with all of the other factors that restrict use including a lack of information, access to materials and legacy effects of policies (Figure 2). Increasing costs are most of the times compensated by increasing margins and reduced production risks, suggesting important benefits on the medium- and long run. But this may not be tempting enough for subsistence, resource-poor farmers.

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

- High upfront costs may disincentivise adoption of agroforestry. Seeds for leguminous trees are not yet included in subsidies programmes and labor costs are relatively high, especially at the beginning.
- Delayed payoffs of soils investments. For farmers who lack the needed cash for the initial investment and who expect concrete benefits relatively quickly, soil management options may not be very attractive.
- Legumes can be detrimental to crop yields, depending on variety, management practice and time (e.g., medium duration varieties and close-spaced planting of pigeon pea, lablab, or Mucuna) [8,9].
- Competing uses of crop residues (traditional practices, cooking fuel collection [pigeon pea stems used as firewood]) may prevent farmers from adopting soil fertility improvement practice.
- Agroforestry species such as Tephrosia do not produce direct grains to food security, only leafy residues and fuelwood, which makes it less attractive to farmers from a food and nutrition security perspective.
- Soil quality is a limiting factor for the establishment and performance of practices like intercropping with annual legumes. Degraded land hotspots cover roughly 40% of country's land [17].
- Practices such as rotations typically requires larger land areas. Average cultivated land per capita in Malawi is 0.24 ha [18]. Shifting to alleycropping can be more viable for farmers with limited land.
- Many farmers are skeptical about planting additional legumes in the absence of adequate markets. Limited means of transportation and inefficiency of middlemen impedes access to formal markets.
- Extension services are critical for adoption of knowledge-intensive practices, yet they are severely underfunded; agricultural budget is at ±1.6% and extension-to-farmer ratio at 1800-2514 [19].

Much of the changes will need to first happen on the farm. But farmers are not ready to work this out on their own. Switching to more resilient technologies requires them to have access to practical knowledge about what technologies are most effective in managing specific risks, to timely weather and market information, and to financial products (insurance, credit, microfinance) that allows them to effectively transfer some of the risks. Basic knowledge and skills to prepare farm budgets and assess cash flows are important for farm risk management. Strategies to reduce some of the variable costs (e.g., cost-sharing methods) are also needed. Alliances between public, private, research and farmers can play a powerful role in closing such loopholes and scale viable investments.

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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 Malawi 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