DISCUSSION PAPER

THE TRUE COST OF MAIZE PRODUCTION

in Zambia's Central Province

Hivos people unlimited

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Soil & More impacts

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ABBREVIATIONS

DNDC	DeNitrification and DeComposition Model
FAO	Food and Agriculture Organization
GHG	Greenhouse Gases
IPCC	Intergovernmental Panel on Climate Change
RUSLE	Revised Universal Soil Loss Equation
SOM	Soil Organic Matter
TCA	True Cost Accounting

1. INTRODUCTION

The global production and output-oriented food production system that has evolved over the last half century has significantly increased agricultural yields all around the globe and brought down the price of food in many places. Today, however, the world is facing multiple severe challenges that have accompanied the rise of this system.

Agriculture has a significant impact on issues like climate change, biodiversity (loss), soil fertility/quality (soil erosion and composition), water use and water pollution, and the general health of ecosystems. The negative impact, or actual costs, of current production methods are not reflected in market prices and hence are passed on or 'externalised' to farmers, society, the environment and future generations. It is clear that the current output-oriented model of agricultural production therefore happens at the expense of future production. There is an increasing consensus that unsustainable farming practices should change, in order not to undermine agriculture's economic foundations, and to secure a sustainable food future.

In these times of a shrinking global natural resource base, the agricultural sector – as well as the national economy in general – must closely monitor developments in soil fertility, access to clean water, energy and so on, and how agricultural practices influence these developments. It is of critical interest to each company in agriculture or the food industry to constantly observe and optimise the management of these most essential resources, simply to maintain agriculture's economic viability.

With environmental challenges growing, an increasing number of stakeholders in different sectors have been calling for policy frameworks to use accounting models that evaluate and monetise external costs. This call for true cost accounting (TCA), or true pricing, has become louder in recent years as the concept has gained recognition. Multiple actors are proposing and experimenting with different methods to integrate externalised costs – such as greenhouse gas emissions, climate change impact, water pollution, soil erosion as well as social and health impacts – into market prices.

Due to its complexity, TCA has not yet materialised in most businesses' daily accounting work. Nevertheless, a growing number of entrepreneurs in farming or processing are asking for practical TCA tools as they see an increasing risk of a changing climate (primarily) impacting their raw material security, and with it their business viability case.

Since 2016, this entrepreneurial concern has been backed by financial auditors, rating agencies and investors. All of the 'Big Four' financial auditors have started to look at how to assess and monetise business risks related to these externalities. For instance, KPMG's case study on the Indian brewery sector clearly showed that business as usual, ignoring externalities, will lead to losses in the near future (KPMG, 2014). Standard & Poor's have published a


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report on how climate change and related environmental risks and opportunities will affect future corporate ratings (S&P Global, 2017). In January 2018, the global investment management corporation BlackRock announced that companies should do more than look for profit maximisation – they should engage with society, or lose BlackRock's interest (Sorkin, 2018). In June 2018, one of the world's largest insurance companies, Allianz, published a report 1) ranking the food and agriculture sector as 'high risk', due to its dependency on shrinking natural resources; and 2) explicitly stating that the use of synthetic inputs increases that risk, and has to be considered in insurance policy conditions (Allianz, 2018).

Hivos recognises that in order to adequately tackle today's and tomorrow's global challenges, unsustainable agricultural practices need to change, and market prices need to reflect the real costs. If, and at what price, agricultural goods will be available in the future is determined by the agricultural practices used today.

Southern Africa has persistent food insecurity, with stunting rates in children up to 40 per cent, mainly due to the limited availability of diverse diets; and a decline in soil fertility, mainly due to production focusing on a single crop and to unsustainable agricultural practices. In this context, Hivos commissioned Soil & More Impacts BV (SMI) to conduct a comparative true cost assessment for intensive, conventional maize production versus sustainable maize production systems in Zambia's Central Province. With the twofold problem of food insecurity and declining soil fertility in mind, this report provides an insight into the real costs of an agricultural system that focuses on maize as the only crop, and offers concrete solutions to mitigate these costs.

It concludes that the actual costs of production in Zambia's current maize cultivation systems are on average 2.5 times higher than what is accounted for/calculated in market prices. This finding is in line with other true cost accounting studies. For instance, a report from the Sustainable Food Trust using true cost accounting finds that UK citizens pay more for food than they realise – in fact, twice as much. The Hidden Cost of UK Food finds that, for each £1 spent on food in the shops, consumers incur an extra £1 in hidden costs (Sustainable Food Trust, 2017). If we want to secure a sustainable future food supply, the agricultural system needs to shift towards more sustainable agricultural practices – like smarter use of crop residues, reducing tillage and growing cover crops. Governments and other policymakers need to create incentives so that all farmers adopt sustainable food production practices. Farmers and agribusiness need to invest in the quality and health of soils – their main production asset – in order to secure a sustainable supply of food in the future.

2. THE TRUE COST ACCOUNTING APPROACH

Introduction and methodology

The aim of this study is to evaluate the hidden costs and benefits of current maize production practices in the Central Province of Zambia, and to compare these with sustainable production practices.

The holistic economic sustainability of a farming system depends heavily on local and product-specific factors – ecologically, but also socioeconomically. One of the core issues for maize growers in Zambia's Central Province is building up and maintaining soil organic matter (SOM). SOM can be considered the farmer's warehouse; the way it is managed and maintained determines whether soil loses or gains nutrients and water. Well-managed SOM can prevent soil erosion and degradation in an increasingly unpredictable and severe climate. SOM management is therefore key to the resilience of a farming system.

This issue is being carefully investigated by financial auditors and insurance companies, as the way a farm manages its SOM also defines future cost price developments – and potential future crop failure, in the case of severe climate events. Poor soil management therefore represents greater financial risk. The general relationship between the development of nutrient costs and management of soil organic matter is shown in Figure 1. It shows that the greater the percentage of organic matter in a farm's soil, the less the farmer has to pay on nutrient inputs.

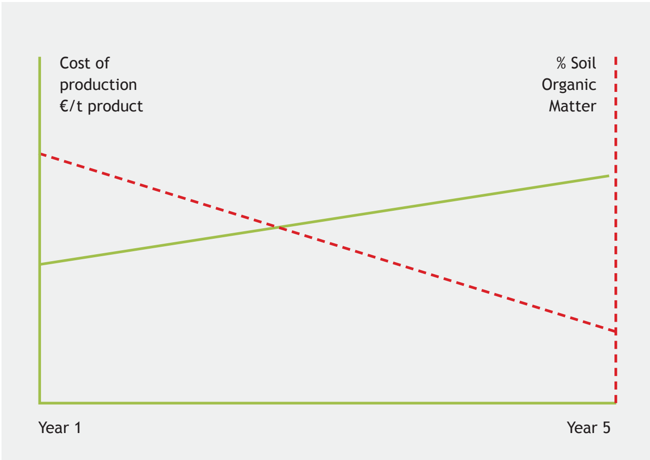

FIGURE 1.

Relationship between input costs and SOM management-

Note: *SOM - soil organic matter.*

The agricultural practices that mostly affect SOM are: fertiliser use; recycling crop residues, such as composting or mulching; soil preparation; and cover crops. As well as these practices, this study also assesses the impacts of water use if applicable, water pollution and the impact of biodiversity on farming systems.

This true cost assessment is based on data provided by Hivos Zambia's local representative, who carried out an on-site assessment of ten representative farms in Zambia's Central Province. These farms represented three different types of farm system. The authors analysed individual parameters based on information provided by the visited farms and statistical data from the Food and Agriculture Organization (FAO), the Intergovernmental Panel on Climate Change (IPCC) and university research worldwide to determine soil carbon, SOM, nutrient contents and dynamics, as well as erosion. They used models such as the Cool Farm Tool, the revised universal soil loss equation (RUSLE) and the DeNitrification and DeComposition Model (DNDC)[1]. These tools and models are widely recognised and used in the food and agricultural sector. Water use was modeled using FAO's ClimWat and CropWat tool, where applicable; the small-scale single-maize farm was assumed not to use irrigation. Potential water pollution, especially by nitrates, phosphates and pesticides, was assessed applying a generic value per hectare provided by the FAO.

Industry and research have differing approaches to monetising the environmental impacts of farming. In 2014, the FAO published a report summarising the results of a three-year multi-stakeholder consultation on TCA conducted with other organisations, such as the Research Institute of Organic Agriculture and the United Nations Environment Programme (FAO, 2014). The report presents a generic approach to the TCA cost estimate at the farm level and presents further economic factors for greenhouse gas emissions, water use and pollution, soil erosion, fertiliser, land use and biodiversity. As the FAO report was generated by independent and well-respected institutions, using a scientific approach and recommended parameters, the authors adopted its parameters for this assessment. The overall approach of this study is based on the Natural Capital Protocol framework[2].

Why soil health matters

The year 2015 was declared by the United Nations as the International Year of the Soil. This was for a good reason. Worldwide, we are destroying our arable soils – the basis for all our food and agriculture – at an alarming rate. Critics say that organic farmers require more land due to their on average slightly lower yields, therefore conventional farming systems make better use of land. In reality though, the loss of fertile soil through intensive, inappropriate agricultural practices is far greater than the additional space needed by organic farming. According to the latest FAO reports, on average the area of arable land per capita worldwide shrank from 4,307 square meters per person in 1960 to about 2,137m2 in 2007 [3]. The reason is simple. Unsustainable farming practices, such as the overuse of mineral fertilisers and related soil erosion, causes about 12 million hectares of arable land a year to be lost globally; meanwhile, in the last 100 years the world population has tripled.

Low prices for agricultural goods put pressure on farmers to intensify agricultural practices, causing soil overuse, depletion and erosion. In the case of Zambia's maize producers, according to this study, the use of fertiliser, soil preparation methods and fallow periods between crops led to the erosion of up to 16 tonnes of topsoil per hectare per year (both water and wind erosion). The FAO assesses the environmental and societal damage caused by soil erosion to cost €22, on average, per tonne of eroded topsoil.

1 See http://www.globaldndc.net/information/about-us-i-1html
2 See http://naturalcapitalcoalition.org/protocol/
3 http://www.fao.org/statistics/en/


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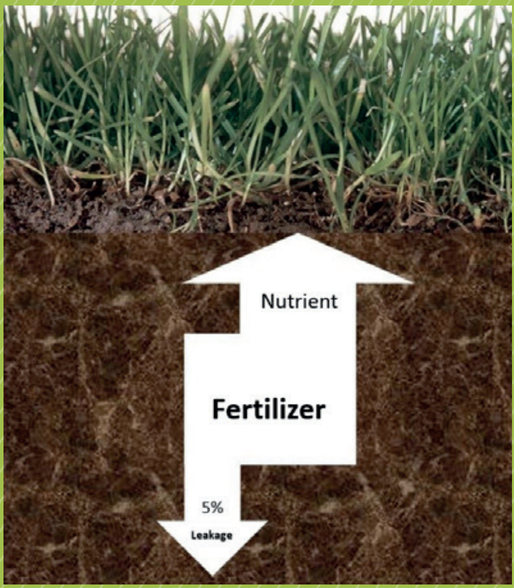
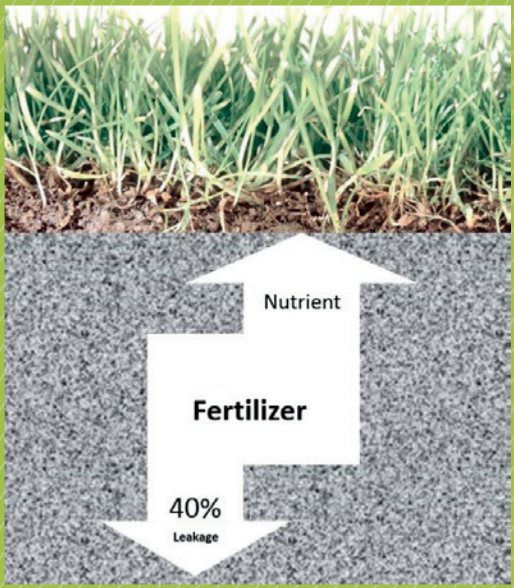
BOX 1. WHY DO WE NEED HEALTHY SOILS?

These images show two different types of soil structure, resulting in different levels of nutrient loss – ranging from 5 per cent for healthy soils to 40 per cent loss for poor soils. The differences can be seen in a single crumb of topsoil under a microscope.

This shows a crystalline mineral or 'clay mineral' structure populated by millions of microorganisms. Closely nested millions of these clay-humus complexes form the whole of the humic topsoil. Their tiny pores allow individual crystals to absorb many times their own weight in water, which is why a good humus soil (left-hand image) is known to have a better water-holding capacity than a comparatively poor soil (right-hand image). This also applies to nutrients. A soil rich in humus allows only a little nutrient loss through leaching. Applying synthetic fertilisers, such as ammonia nitrate or urea (mineral salts), interferes with or even destroys microbial life, causing the soil structure to collapse. Depending on the type of soil, the loss of structure either leads to severe wind or water erosion or extreme compaction. In both cases,, the soil's capacity to hold water and nutrient deteriorates, as both increasingly run off. This ever-growing nutrient loss means more fertiliser needs to be applied, which, given rising fertiliser prices, leads to a significant cost increase - not to mention the impact on groundwater and the environment in general. Applying compost, however, regenerates the soil, reducing nutrient leaching and optimising nutrient efficiency.



HEALTHY SOIL STRUCTURE
means low leakage



POOR SOIL STRUCTURE
means high leakage

Apart from replacing synthetic fertilisers with compost, the main options for more sustainable maize production in Zambia's Central province are less tillage and cover crops, as well as diversifying the crop rotation. Compost applications, mulch and less tillage are not only good for soil fertility (see Box 1) but also for climate protection. Soil is the world's largest terrestrial carbon reservoir, more than the above-ground biomass and underground inorganic carbon combined.Through erosion or other soil degradation, this carbon is released as total carbon or carbon dioxide. Sustainable farming preserves these carbons in the soil or even sequesters additional CO_2. Under current maize farming practices in Zambia however, up to three tonnes of carbon dioxide equivalent are emitted per hectare per year.

Through better use of crop residue for composting or mulching, as well as reducing tillage and more use of cover crops, these emissions are not only reduced to about a third, but up to a further 1.5 tonnes of carbon dioxide are sequestered per hectare per year. This means that by using more sustainable farming practices, maize farming systems may become carbon neutral or even carbon positive. Since soil carbon is an important factor for soil and humus genesis, soil and humus will be at least maintained by these sustainable practices, if not built up over time.

For this reason, the global agribusiness sector agrees that soil organic matter is the key indicator for sustainable agricultural production. A decrease in SOM means that lower quantities of resources, that is nutrients and water, are available for production and thus production systems are less efficient. The lower SOM level in the right-hand picture in Box 1 results in the leaching of applied synthetic fertilisers. This comes at a cost for both the farmer and the policymakers. The cost of fertiliser constitutes an important part of the cost of production; if 40% of the fertiliser cannot be absorbed by the maize, production cost increases. For policymakers, there is a strong incentive to reflect on the use of public resources. One study shows that in 2013 the cost of the Zambian fertiliser support programme was almost 500,000,000 Zambian kwacha (€62,000,000) (Zinnbauer et al., 2018). If 40% leaks away, then 40% of this public investment – or almost €25,000,000 – leaks away. On the other hand, if this public investment supports building up SOM, than it leads to a more efficient uptake of nutrients. The results of building up SOM are presented in Section 3 on page 19 on expected future earnings.

FAO defines the cost of carbon dioxide emissions for the environment and society at €100 per tonne of CO2e (FAO, 2014). Factoring this amount into the cost/benefit calculation of conventional maize farms, additional costs due to the release of carbon dioxide amount to €120 per hectare for small-scale single-crop maize farms, or even up to €330 for large-scale farms. These costs are currently not accounted for. As mentioned above, more sustainable maize not only avoids these costs but sequesters carbon dioxide. Valued using the same factor, in the best case the small-scale mixed cropping systems result in a slightly positive value, as more carbon dioxide is sequestered than emitted.

Carbon sequestration, together with compost application and crop residue management, are therefore important ingredients for the build-up of humus and topsoil. Humus in turn has ample positive effects. First, humus is a supplier of top soil material. Second – and above all – humus is home to millions of microorganisms, which ensure natural soil fertility and health. Growing maize in combination with other crops, using sustainable methods, builds up to 1 tonne of humus-rich topsoil per hectare per year. If these better practices are applied over five to seven years, erosion can be fully compensated for and a small-scale multi-crop maize farming system becomes net positive. In other words, through the continued build-up of soil, affecting water and nutrient management, a farm generates a net benefit for itself, society, the environment and the national economy.

Business-as-usual maize cultivation in Zambia, using chemical fertilisers and pest and disease control agents, impacts on water pollution and biodiversity, causing environmental damage at a cost of over €120 per hectare per year. The more sustainable maize farming alternative can still leach applied compost, but causes damage at just over €14 per hectare per year, a significantly lower environmental damage to water quality and biodiversity. Using a conservative approach, the water management in the more sustainable scenario was found to be only 10% more efficient; although studies indicate that an increased SOM level could improve the water management efficiency by 30%[4] and more.

> Through better use of crop residue for composting or mulching, as well as reducing tillage and more use of cover crops, these emissions are not only reduced to about a third, but up to a further 1.5 tonnes of carbon dioxide are sequestered per hectare per year.

Baseline characteristics of three maize production systems

This true cost assessment analysed ten representative farms in Zambia's Central Province, comprising three different types:

1. Small-scale farms producing maize only (3 farms)
2. Small-scale farms with a mixed cropping system, (5 farms) and
3. Larger-scale farms with a mixed cropping system. (2 farms)

All farms are located close to the town of Kabwe in the Central Province of Zambia. Table 1 shows the characteristics of the three maize production systems.
The small-scale maize monocrop farms had no irrigation and soil was left fallow for about half the year. Relatively small quantities of synthetic fertiliser were applied resulting in relatively low yields. In addition to these, some manure was applied and some crop residues were left in the field.
The small-scale farms in this study used a mixed cropping system to cultivate maize in rotation with vegetables such as cabbage and onions. They used irrigation and slightly more fertiliser than the single-crop farms, while yields were significantly higher. Some of the farmers reported reduced tillage but still indicated a soil preparation depth of 30 centimetres. Apart from that, some of the assessed farmers applied very small amounts of compost and manure, and some planted cover crops while the crop residues were either left on the field or burnt.

4 https://www.sciencedirect.com/science/article/pii/S0167880998001133

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BOX 2. FARMER TESTIMONY: MAIZE MONOCROPPING

Mrs Chingambu has been growing maize for the past 20 years, both for animal feed and for human consumption. Her harvest has gradually reduced over time, causing her to wonder if fellow farmers had bewitched her land.

She observed the following:

- Her best harvest decreased from 45 bags (50 kilogrammes each) to only 20 bags
- Her maize was becoming increasingly affected by disease and infections
- Her seeds were not high quality and therefore not selling at their former higher prices
- Her plants appeared to be unhealthy at various stages, and
- Her fields were full of ridges.

Mrs. Chingambu intends to shift her farming to livestock only, since lack of profit means she is unable to pay the debt accumulated from buying fertilisers and chemicals. The soil on her farm has eroded due to over-tillage and maize monocropping - a practice which does not hold the soil together, unlike grasses and legumes which bind together and protect the soil's surface.

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BOX 3. FARMER TESTIMONY: ORGANIC FARMING

Mr and Mrs Moyo have been practicing organic farming since 2012 and have seen improvements in both revenues and soil. Mr Moyo explained the techniques they use:

- Rotating maize with legume cover crops and weeding frequently
- Adding animal and green manure to improve soil fertility
- Intercropping with beans (legumes such as beans or peas fix nitrogen in the soil, which is required for healthy maize growth)
- Planting hedges around their maize to discourage natural enemies
- Regularly slashing the green manure crop and leaving it to cover the soil (a field with legume cover crops and shrubs left fallow for one to three years rejuvenates the soil and suppresses weeds), and
- Regularly pruning legume shrubs and using the remnants to cover the soil.

These practices have led to a good yield, as the family is gathering about 43 bags of maize (weighing 50 kilogrammes each) per harvest. Their seeds are germinating well and are good for processing and marketing. Their crops are resistant (or at least tolerant) to typical pests, diseases and weeds, and adapt well to the rainy season. The Moyo family is satisfied with the results of their organic farming practices and are able to feed themselves wholly from the farm, eating healthily and cheaply.

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The assessed larger-scale farms use a mixed cropping system to cultivate maize in rotation with leguminous crops such as field beans or soybeans. They use various irrigation systems and relatively high amounts of fertilisers, resulting in comparably good yields. Some of the assessed farms reported using small quantities of compost and manure. One farm made partial use of cover crops and crop residues were left in the field. No burning was reported.

Table 1. Characteristics of the three maize production systems (averages per farming system)

	Small monocrop farms (3 farms assessed)	Small mixed crop farms (5 farms assessed)	Large mixed crop farms (2 farms assessed)
Average % organic matter in soil	0.83%	1.24%	0.30%
Prevailing soil pH	5.40pH	5.52pH	5.05pH
Prevailing Irrigation system used	No	Drip, flood, sprinkler	Sprinkler
Average farm area in hectares	1.33	5	130
Average number of shade trees per hectare	13.83	8.20	0.55
Prevailing crop rotation	No	Maize, cabbage, onion	Maize, soybeans, field beans
Average maize yield, metriuc tonnes/hectare	0.80	3.05	3.25
Has productivity changed in recent years?	Yes	Yes	Yes, no
Average synthetic nitrogen, kilogramme/hectare/year	101.25	150.80	155.00
Average synthetic phosphorus, kilogramme/hectare/year	79.17	112.00	120.00
Average synthetic potassium, kilogramme/hectare/year	39.58	66.00	110.00
Compost, kilogramme/hectare/year	-	-	2.50
Animal manure, kilogramme / hectare/year	33.33	50.00	1.00
Lime, kilogramme/hectare/year	-	-	1.75
Has the amount of fertiliser used increased in recent years?	Yes	No	No
Did you start one of the following practices in the past 20 years?			
Compost application			Yes
Reduced tillage		Yes	
Green manure/cover crops		Yes	Yes
Manure application	Yes	Yes	Yes
Crop residue incorporation	Yes	Yes	Yes
Number of weeks soil is left fallow between two crops	20	13.6	10
Prevailing crop residue management	Mulching	Burning	Mulching
Tillage depth in centimetres	30.00	30.00	25.00
Baseline evaluation based on the average performance within each category	Impact per hectare is highest and output is lowest, resulting in an unsustainably high impact overall. Also, single crop production increases risk of pests/disease.	Second highest impact per hectare, but high output through diversified rotation. Some better practices are already in use which may already lead to better soil organic matter; however, burning crop residues is bad practice.	Lowest impact per hectare, but output is limited due to rotation with intensively cultivated crops. Some better practices are already in use but the intensive farming approach leads to high impact per output.

3. RESULTS OF THE TRUE COST ASSESSMENT

This true cost assessment investigates if there is an economic reason to change the current intensive maize-based farming systems in Zambia to a more diverse and sustainable way of farming.

The assessment was based on data from three representative maize farming systems in Zambia's Central Province, shown in Table 1: a small-scale maize monocrop system; a small-scale multi-crop system; and a larger-scale multi-crop system. In addition, the authors modelled an alternative scenario for maize cultivation, based on natural fertilisers, more use of cover crops and less tillage. A key element of this alternative scenario is better use of crop residues after harvest, which are currently either left on the field for uncontrolled decay or are burnt. Instead, returning crop residues to the soil through composting or mulch recycles nutrients, saves fertiliser cost in the following season and stimulates the build-up of humus, improving the farm system's resilience and economic efficiency over time.
The assessment follows the guidelines of the Natural Capital Protocol framework to calculate the environmental cost of the following parameters: 1) greenhouse gas emissions; 2) carbon sequestration; 3) water use; 4) water pollution; 5) soil erosion; 6) humus build-up; and 7) biodiversity.

The environmental impact of current farming practices

Table 2 and Figures 2 to 7 show the results of the TCA of three maize production systems, according to their estimated current production costs (provided by local experts). Based on local circumstances, different production costs are assumed for each system. For each alternative scenario using better practices, an additional cost of €100 per hectare is assumed, covering the costs of cover crop seeds, compost and so on.

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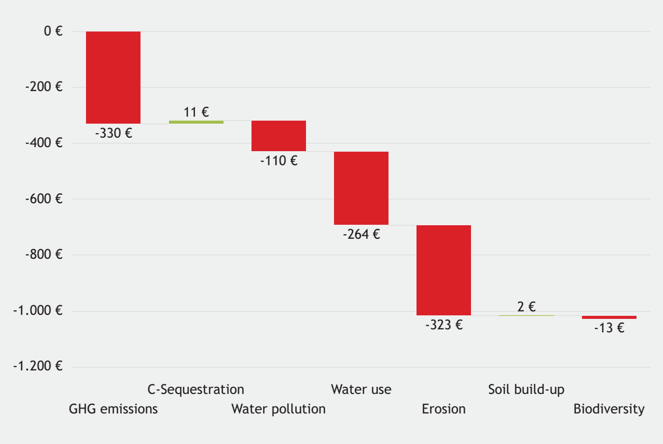
> The business-as-usual maize farming system leads to an overall environmental external cost ranging from €552 per hectare per year for small-scale maize monocropping and €992 for small-scale mixed systems, to €1,030 for large-scale mixed systems. This implies that the true cost of maize production is 2 to 2.5 times higher than what is actually paid for.

Table 2. Results of true cost accounting for maize production systems

	Large scale mixed system		Small scale single maize system		Small scale mixed system		
	Baseline - large-scale maize rotation	Scenario - large-scale maize rotation	Baseline - maize monocrop system	Scenario - maize monocrop system	Baseline - small-scale maize rotation	Scenario - small-scale maize rotation	Scenario 2 - small-scale maize rotation (+7 years)
GHG emissions	-329,99 €	-109,90 €	-122,12 €	-83,88 €	-313,80 €	-139,26 €	-146,48 €
C-Sequestration	10,66 €	48,83 €	13,08 €	14,34 €	26,69 €	207,40 €	400,60 €
Water pollution	-109,58 €	-14,58 €	-109,58 €	-14,58 €	-109,58 €	-14,58 €	-14,58 €
Water use	-264,38 €	-237,94 €	- €	- €	-264,38 €	-237,94 €	-237,94 €
Erosion	-323,06 €	-49,04 €	-323,06 €	-49,04 €	-323,06 €	-49,04 €	-49,04 €
Soil build-up	1,91 €	87,43 €	2,34 €	2,57 €	4,78 €	37,14 €	71,74 €
Biodiversity	-12,89 €	- €	-12,89 €	- €	-12,89 €	- €	- €
Total/ha	-1.027,33 €	-275,20 €	-552,23 €	-130,59 €	-992,24 €	-196,27 €	24,31 €
Total/kg	-0,40 €	-0,14 €	-0,71 €	-0,24 €	-0,17 €	-0,03 €	0,03 €
Add. scenario cost/ha: cover crops & compost		100,00 €		100,00 €		100,00 €	100,00 €
Current cost of production/ha	670,00 €	670,00 €	480,00 €	480,00 €	575,00 €	575,00 €	575,00 €
True cost of production/ha	1.697,33 €	1.045,20 €	1.032,23 €	710,59 €	1.567,24 €	871,27 €	650,69 €
% true/current cost/ha	253%	156%	215%	148%	273%	152%	113%
Net result	**-1.027,33 €**	**-275,20 €**	**-552,23 €**	**-130,59 €**	**-992,24 €**	**-196,27 €**	**24,31 €**

FIGURE 3.

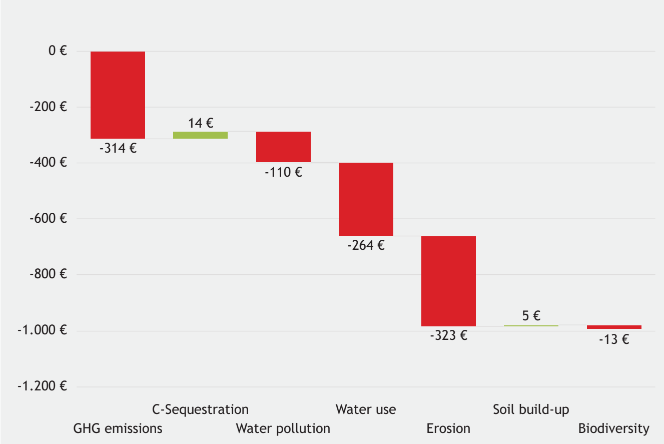
Costs and benefits for large-scale maize rotation in Zambia, €/hectare



Note: *Monetary values for each parameter are based on recommendations from the FAO. GHG - greenhouse gas.*

FIGURE 4.

Costs and benefits for small-scale maize rotation in Zambia, €/hectare



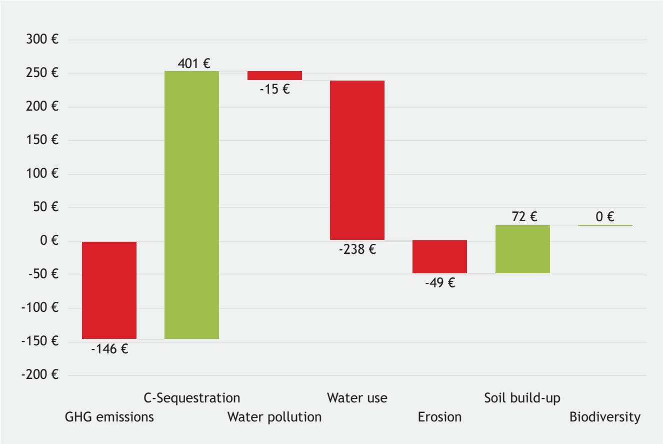
Note: *Monetary values for each parameter are based on recommendations from the FAO. GHG - greenhouse gas.*

The baseline columns in Table 2 show the current cost of maize production for a large-scale mixed system (€670 per hectare), small-scale mono-maize system (€480/ha) and small-scale mixed system (€575/ha). For each of the parameters of the Natural Capital Protocol framework, the assessment uses the monetary values defined by the FAO (2014). The business-as-usual maize farming system leads to an overall environmental external cost ranging from €552 per hectare per year for small-scale maize monocropping and €992 for small-scale mixed systems, to €1,030 for large-scale mixed systems. This implies that the true cost of maize production is 2 to 2.5 times higher than what is actually paid for.

Broken down to an average cost per kilogramme of product, the external costs range from €0.17 to €0.71 per year. The FAO shows that a total area of slightly more than 3 million hectares is under maize production in Zambia (FAO, 2018). This implies that the total true cost of the environmental externalities of Zambia's maize production amounts to a staggering €1.65 to €3.1 billion per year.

FIGURE 5.

Costs and benefits for maize monocrop system in Zambia, €/hectare



Note: *Monetary values for each parameter are based on recommendations from the FAO. GHG - greenhouse gas.*

FIGURE 6.

Cost/benefit comparison of different systems, € per hectare

Note: *Monetary values for each parameter are based on recommendations from the FAO. GHG - greenhouse gas. Scenario 2 - after seven years of sustainable farming practices.*

The environmental impact of sustainable farming practices

Table 2 and Figures 2 to 7 also show the environmental costs of an alternative scenario, where maize is grown more sustainably. This includes the following sustainable farming practices: 1) using crop residues for composting or mulching instead of spreading or burning; 2) reducing tillage; and 3) systematically using cover crops to loosen the soil, suppress weeds, keep the soil moist and cool and fix nitrogen.

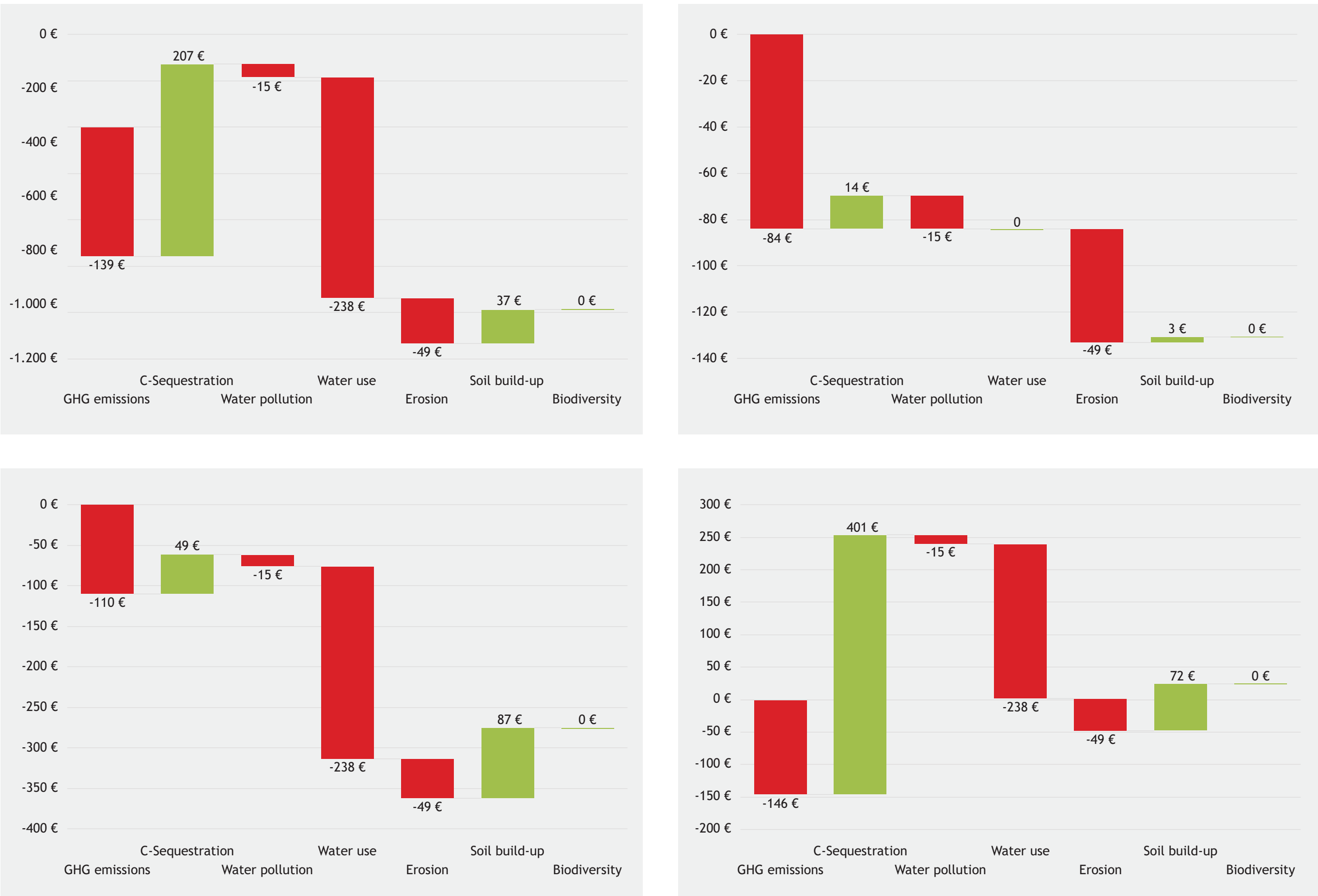
Using these practices can reduce the environmental costs significantly per hectare per year. This is shown in the sustainable scenario columns: the cost of maize production for a large-scale mixed system is €275 per hectare, a small-scale mono-maize system is €130/ha, and a small-scale mixed system is €196/ha. Broken down to an average cost per kilogramme of product, these external costs are limited to a range of €0.03 to €0.24 per year compared to €0.17 to €0.71 in the baseline case.

Compared to the business-as-usual scenario, the significant difference in the sustainable alternative is that carbon is actually sequestered, and more soil is built up than eroded. These impacts lead to an increasingly resilient farming system, making better use of nutrients and water, and reducing the risk of production costs increasing and crops failing. This scenario moves the farmers from a vicious to a virtuous production cycle.

For the alternative scenario, scenario 2 shows the expected effects after seven years of using more sustainable practices for small-scale mixed systems. These show a net positive result of €24.31 per hectare. The additional requirement of €100 per hectare for better practices still leads to a slight increase in production costs over time, but the underlying business case is net positive.

FIGURE 7

Cost/benefit results for sustainable maize production scenarios



Note: *Monetary values for each parameter are based on recommendations from the FAO. GHG - greenhouse gas.*

The social and health impact of maize-based systems

This study has focused on the environmental externalities of maize production systems. However, their health-related impacts could also be evaluated. The FAO is evaluating the social and health impact of various farming practices and their related costs, but its overall TCA frameworks are still under development. For instance, the FAO's definition of cost related to health damage, due for example to pesticide-contaminated food, is still vague. This includes the food's nutritional value. Models such as the 'disability-adjusted life years' model allow individual health damage through contaminated food to be quantified and monetised, but doesn't yet include the value creation of healthy food. It is known that the contamination level of our food and the nutritional value of our diets have a significant impact on human health, and there are several studies and projects on the way to develop robust models for these aspects, which could be used for a follow-up assessment.

Apart from the health and nutrition aspects, other socioeconomic aspects – such as loss of habitat, migration and conflicts – result increasingly from non-sustainable farming practices, causing economic losses at an individual and national level. These impacts and related costs are of course difficult to quantify, and are therefore often seen as too vague. Yet these impacts and costs are already very real for millions of people, and should be assessed adequately – or at least farming systems potentially causing these impacts shouldn't be incentivised further. Unsustainable, short-term, one-sided, profit-driven farming systems provoke conflict over fertile soil, clean water, raw materials and feedstock for animals – which can lead to local or even regional unrest, or force people to leave their homes.

To include these real, understandable, but difficult-to-quantify parameters, the FAO has carried out comprehensive surveys to define the costs associated with loss of livelihood due to soil erosion and individual health damage through, for instance, pest and disease control or social conflicts over resources. Overall, the FAO estimates the social costs of unsustainable farming practices to be €0.33 per hectare per year, of which almost 90% can be attributed to using conventional pest and disease control. This number may sound small, but if for example a person is responsible for managing pest and disease control on a farm of about 100 hectares, the accumulated cost of individual health damage would be €3,000. However, this study took a conservative approach and did not consider these potential individual health damages due to a lack of data.

Resilience of different maize production systems: expected future earnings

Unsustainable farming practices reduce soil organic matter, leading to increasing production costs as nutrients and water are lost through leaching and erosion. These costs can be forecasted, as well as their impact on the expected future earnings of the farmer. This can likewise be applied to companies buying raw materials from farmers. If buyers keep pushing down prices or otherwise incentivise non-sustainable farming practices, production costs will go up, along with the risk of crop failure. Again, this negatively affects the expected future earning of buying companies, since the whole sector will be affected.

For this forecast, the study applied the DeNitrification and DeComposition (DNDC) model, using daily weather and farming management data. It also used verified soil data derived from global ISRIC databases.[5] The result of DNDC is a calibrated yield forecast. Erosion was considered using field data, the RUSLE equation and international study results. Input costs were calculated using the SMI project database and divided by the DNDC yield forecast result. The model considers both positive and negative trends related to managing SOM, which defines water and nutrient efficiency in a farming system.

5 See https://soilgrids.org/#!/?layer=TAXNWRB_250m&vector=1

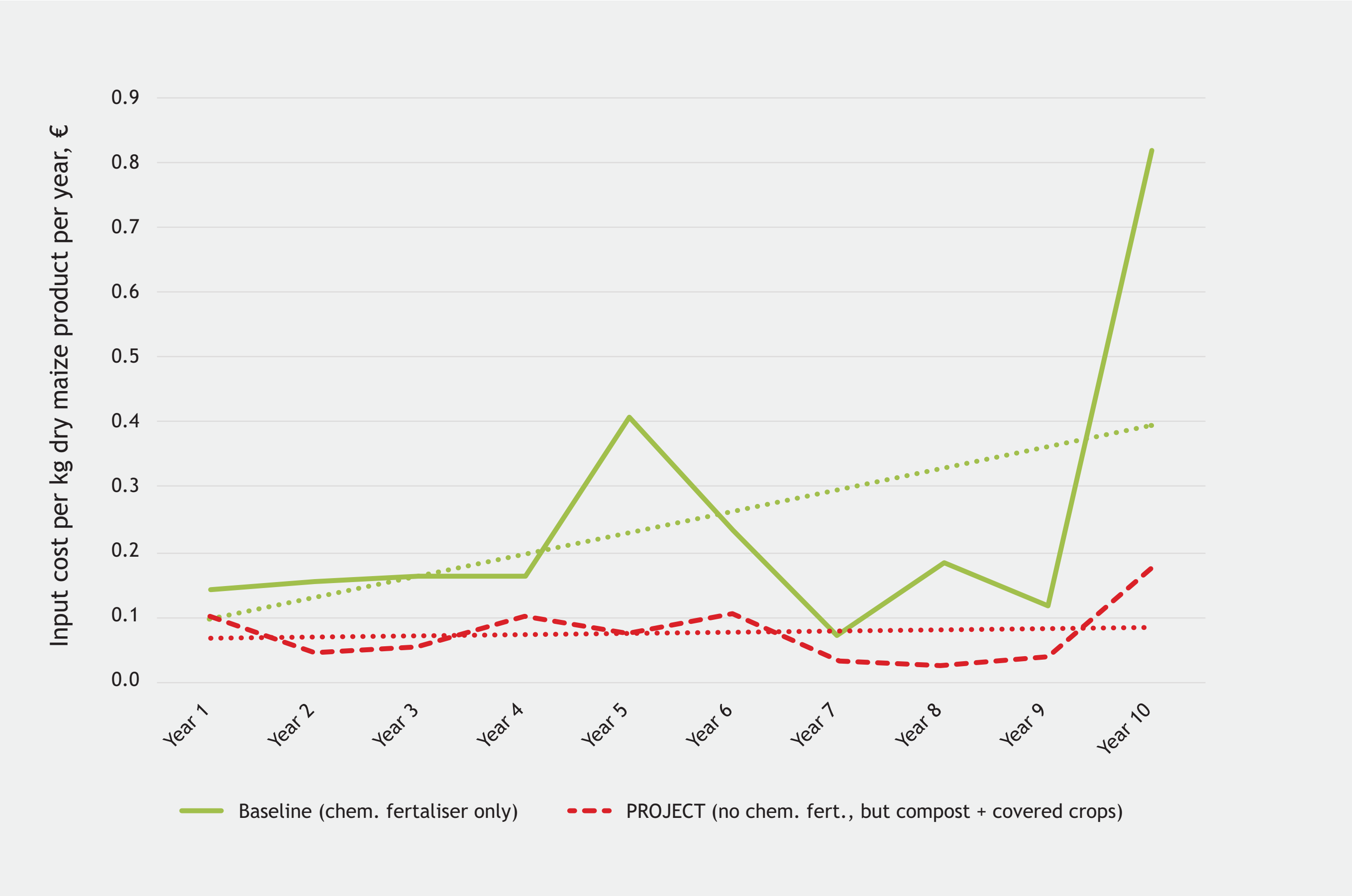


FIGURE 8

Maize food system resilience: conventional versus organic practices

Note: *Calculations based on 1 hectare of sandy loam soil in Central Zambia; water and wind erosion considered.*

Figure 8 shows the baseline scenario, where continuous synthetic fertilisation and conventional tillage cause the soil to erode and both nutrient and water efficiency to decrease. It also shows the trend in production costs if compost is applied and cover crops used (in both cases the input costs are considered). The trend clearly shows that production costs increase in the baseline scenario (conventional maize farming), while the project scenario (sustainable practices) represents a stable, less volatile and thus more resilient farming system. This shows the importance of taking the sustainable use of resources into account.

These costs are currently not accounted for, but might be considered by organisations such as KPMG and Standard & Poor's in their new valuation and rating schemes. As all three assessed scenarios have higher soil erosion than soil build-up, and more greenhouse gas emissions than sequestration, the systems' resilience – or in economic terms, efficiency – will only become poorer over time. These assumptions are therefore being carefully investigated by financial auditors (e.g. KPMG), rating agencies (e.g. Standard & Poor's), banks (e.g. Triodos) and insurance companies (e.g. Allianz) who realise that ignoring these external factors will affect the accuracy of their credit or risk ratings and may lead to unforeseen losses or defaults.

4. INCENTIVES FOR DIVERSIFYING MAIZE-BASED FOOD PRODUCTION

The true cost assessment of environmental externalities has shown that the real cost of maize production (€1,697 per hectare and year) is on average 2 to 2.5 times higher than what is actually being paid for (€670). In other words, maize is produced at the expense of future production potential.

However, when more sustainable farming practices are used, the small-scale mixed crop system can have an almost neutral environmental cost that becomes a net benefit after five to seven years of better practices (see Section 3.4 above). If we promote and incentivise a farming system that reduces risk for farmers by using sustainable practices, then it improves the resilience of the maize-based farming system. In turn, the dramatic volatility of food prices will reduce. Otherwise, steeply raising the cost of living through unsustainable farming practices will cause increased poverty, and with it, social unrest.

To achieve this, policy makers should incentivise Zambian maize farmers to adopt balanced crop rotation, reducing the amount of time fields lie fallow by cultivating cover crops. Cover crops are already partially in use but should be used systematically. Cover crops fix nitrogen, keep the soil moist and cool, suppress weeds and build up root biomass, increasing SOM and microbial life. If deep-rooting cover crop varieties are used, tillage could be reduced further, as the roots will loosen the soil. In addition, crop residues and mulch should be composted through small-scale, on-site compost piles. Larger farms could set up composting facilities to provide compost to the market. While mulching crop residues in these climates mostly leads to an oxidisation of the carbons and nutrients in the biomass, composting transforms them into humus, providing the plants with the nutrients they need. Based on collected data from the field, it seems feasible to apply two tonnes of compost per hectare per year. If these practices are promoted and incentivised, Zambian maize producers will get out of the vicious circle of needing more and more fertiliser per year at higher and higher prices, and enter a virtuous circle that benefits society, environment and the farm balance sheet.

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