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Assessing and improving organic matter, nutrient dynamics and profitability of smallholder farms in Ethiopia and Kenya

Proof of concept of using the whole farm model FarmDESIGN for prioritization of GIZ development interventions

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Assessing and improving organic matter, nutrient dynamics and profitability of smallholder farms in Ethiopia and Kenya

Proof of concept of using the whole farm model FarmDESIGN for prioritization of GIZ development interventions

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1. Introduction

Smallholder farming systems and agro-ecologies of smallholder farming systems in Sub-Sahara Africa are highly heterogeneous, diverse and dynamic. Trade-offs can occur between productive, environmental and social performance indicators, for example between agricultural production and environmental impact. Such trade-offs influence the adoptability, impact and sustainability of possible innovations and future pathways (Giller et al. 2011). Changes in available technologies, market conditions and policies can lead to increased efficiency and potentially reduce the trade-offs between performance criteria. Decisions on the use of technologies are dependent on farmer strategies (defined as a consistent set of practices aimed at reaching a particular goal) for allocation of their limited financial, labour and nutrient resources. For example, a farmer might choose to not adopt a technology that is superior in terms of productivity because he or she cannot satisfy the increased labour demands. These decisions also have implications for the sustainability of their farming systems (Tittonell, 2008). There are no silver bullets and development interventions that work everywhere. Therefore, targeting of interventions and technologies has become a key concept in tackling adoption (Giller et al. 2011).

Quantitative systems modelling and ex-ante impact assessment can help to systematically explore trade-off frontiers and potential impacts, which can be expected to be different for farm types with contrasting biophysical conditions and resource endowment (Groot et al. 2012). Development actors, like GIZ, aim at optimally targeting their interventions to maximize impact. In collaboration with national institutes, the GIZ Soil Protection and Rehabilitation for Food Security global program is currently planning and implementing soil conserving agricultural practices/methods/technologies in five countries – Ethiopia, Benin, Burkina Faso, Kenya and India. To support GIZ in these new German development cooperation efforts, we aimed to deliver a proof of concept that quantitative farm modelling can assess potential impacts to assist in program design. We chose case studies from two GIZ target countries – Kenya and Ethiopia. The two farms are contrasting in terms of commercialization, crop-livestock integration and agro-ecology. To make the study as applied and useful as possible, “what-if” scenario-analyses were carried out with scenarios reflecting some of the most promising soil conservation practices promoted by GIZ and other development actors in the region.

2. Materials & Methods

The study sites

The Ethiopian farm is located in Sinana, Bale Zone, in the Oromia Region in the plains of the wheat belt of Ethiopia. The Kenyan farm is located in Mambai sub-location in the northern, upland tea-growing areas of Vihiga County in western Kenya. Both study sites differ in terms of agro-ecological zones, length of the growing season and the livestock density (Figure 1). The Ethiopian farm is located in the sub-humid, cool highland of Ethiopia at around 2000 m above sea level. The region receives unimodal rains and thus has only one cropping season per year from July to December followed by a dry season from December to June with some little rains in April and May. The Kenyan farm is located in the humid highlands of western Kenya (1500 m above sea level). This region has bimodal rainfalls and thus two cropping seasons: from March until July and September until December. Livestock density is higher in western Kenya than it is in Oromia, Ethiopia (Figure 1). Population density is high in Mambai sub-location, with 1000 people/km^2.

The bio-economic whole farm model FarmDESIGN

The farm scale model FarmDESIGN was used for describing and explaining the outcomes of the current configuration of selected farms as well as for exploring alternative farm configurations. It is a tool which supports evaluation and re-design of mixed farming systems (Groot et al. 2012). The user follows a learning cycle according to the DEED concept: Describe, Explain, Explore and Design (Giller et al. 2011, Tittonell 2008). The farm is described by its farming system components and their biological and economic characteristics. In this section of the model, the user can define decision variables that the model can use for the exploration of farm possibilities to meet specific objectives defined later on. From this point the outcomes of the current farm configuration are calculated. Farm performance is explained in terms of crop areas, feed balances, soil organic matter (SOM) balance, profit, labour balances, and nutrient cycles among others.

In this section, objectives and constraints can be defined for farm exploration.

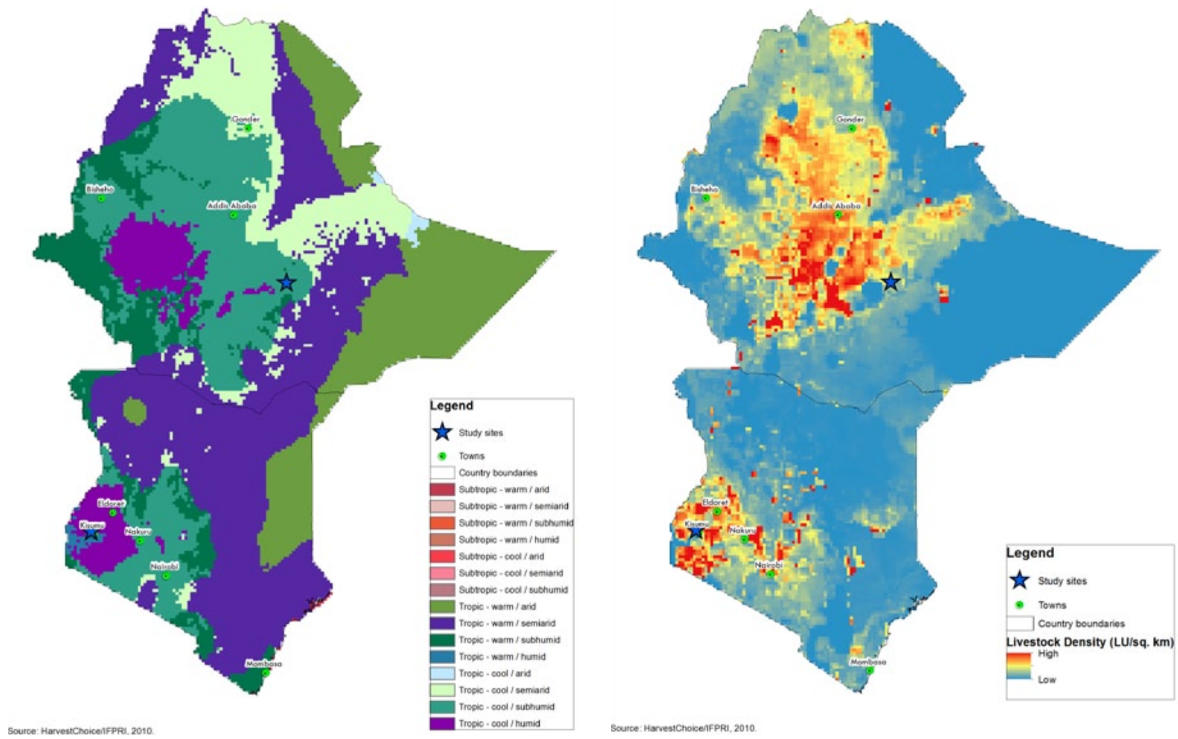

Figure 1: Agro-ecological zones (left) and livestock density (right) of sites in Ethiopia and Kenya

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Objectives can be, for instance, decreasing SOM loss and increasing profitability. Constraints can be the livestock feed balance and making sure that animals are kept properly fed. Other constraints could be the amount of labour available. During the exploration phase, FarmDESIGN will generate a number of farm configurations. The optimization of the farm will meet the set objectives and constraints using the defined variables. All these options translate into individual farms to be compared to the current farm. Then the most suitable configuration can be chosen for re-designing the farm.

For the purpose of this study the exploration function of the model was not used since specific scenarios were translated directly into different farm configurations. These different farm configurations were entered and the outcomes were compared. In this case study, FarmDESIGN-relevant soil parameters namely pH, organic carbon, nitrogen, bulk density, soil depth and soil texture were derived from ISRIC's Soil property maps of Africa (Hengl et al. 2015). Major differences lie in the annual mean temperature and the number of days at which the pF is below 3.5. The farm in Ethiopia is located at a higher altitude where the annual temperature is on average cooler and drier than at the farm in western Kenya.

Case study farm: Ethiopia

Unlike the majority of farmers in the rest of the country, farms in the wheat belt (Arsi and Bale zone) are quite large and mostly rely on rented combiners for harvesting wheat. In the wheat belt, land is relatively abundant but pressure on it is increasing mainly due to the expansion of cereal crops: communal grazing grounds have disappeared and a lack of animal feeds was the main problem mentioned by farmers in the area when asked about challenges they face. Out of eight detailed farm interviews conducted for CIMMYT Wheat, a representative farm in terms of resources and farming practices was selected for modelling. The case study farm has 11 household members. The cultivated area is 7.125 ha, which is divided into 12 fields. Wheat is the main crop; different improved varieties are planted on 8 fields, the largest being 1.5 ha. Maize, oats, wheat, barley, and faba bean are planted in the other four fields during both the main and minor seasons. The average wheat yield on the farm ranges from 3 t ha^{-1} to about 3.5 t ha^{-1}. Barley grain yields an average of 3.6 t ha^{-1}. Faba beans yield 1.7 t ha^{-1}, which are all for home consumption while all residues are fed to livestock. Oats grain yields are the lowest (0.8 t ha^{-1}). Maize yields are 2.4 t ha^{-1}. Wheat is mostly grown as a cash crop (65% to 80% sold) and the rest is used for home consumption. Close to 75 percent of the wheat and barley residues are fed to animals. After grazing, the remainder (about 20% of total residues) is used for construction. Oat and maize grains are used for household consumption. High post-harvest losses of crop residues (up to 45% at times) may occur. Apart from crop residues, livestock is fed wheat bran (2500 kg are bought per year). Di-ammonium phosphate (DAP), urea, pesticides, fungicides and herbicides are used on the farm for fertilization of the crops and treatment against pests and weeds.

For modelling purposes we assumed that these inputs are applied equally across all fields, i.e. at a rate of 46 kg N ha^{-1}. Manure produced in the yard is collected and applied to all fields at an equal rate of approximately 1 t ha^{-1}. Additional manure is deposited directly when the livestock is out grazing on stubble. The farm has a total of eight cattle: two improved oxen for sale per year, two local oxen for traction, two improved cows which produce on average close to three litres of milk per day for home consumption, one local heifer for sale and one improved calf. There is also one donkey and one horse used for transport and other farm activities. The animals spend 24 hours in a non-roofed enclosure during the growing season. For the rest of the year, especially during the dry season, the livestock spends about ten hours per day grazing on crop stubble and spend the remaining 14 hours in the yard.

Case study farm: Kenya

This farm is located in western Kenya in Vihiga County. The household is small with only the husband as head of the household and his wife. The farmer's land holdings are close to 0.4 ha which is divided into five fields: two crop fields, two tree plots and one Napier field. The maize-bean intercrop is the largest field (about 0.2 ha) and the surface area of the tea plot is approximately 0.1 ha. The smallest fields are the sole banana plot (0.03 ha) and the eucalyptus tree plot (0.048 ha) whose size is more or less similar to the Napier field (0.05 ha). The small tea plot yields close to 12 t FW ha^{-1} year^{-1} picked throughout the year, which is all sold. Maize grain yield is 2 t ha^{-1} and bean yield is about 400 kg ha^{-1}; both for home consumption only. Banana bunches harvested amount to 7.8 t ha^{-1} and are mainly for home consumption (one quarter is sold). Maize residue and banana stems are all fed to the livestock, and bean residues are burnt to make lye for cooking. The Napier field yields approximately 14 t ha^{-1} year^{-1}. Inputs used on the farm include manure collected from the yard and barn as well as purchased DAP and CAN (Calcium Ammonium Nitrate) and NPK (20-5-5) fertilizer supplied on loan by the tea buying company. Manure produced – about 1.6 t DM – in the yard and barn is all applied to the banana trees. The supplied NPK fertilizer is applied at a rate of 90 kg N ha^{-1} to the tea plot. Both CAN and DAP are applied at a rate summing up to 15 kg N ha^{-1} and 10 kg P ha^{-1} in the maize-bean plot.

The farmer has two crossbreed adult cows and they spend six hours in the yard during the day and the remaining hours in the barn. They produce an average of close to two litres of milk a day; about 84 percent is for home consumption and the calves suckle the rest. The farmer keeps about 50 local chickens: 12 layers (eggs for home consumption) and the rest broilers. Cattle is fed roadside grass, Napier produced on farm, and some of the crop residues. Comparing to another farming system survey from Vihiga, this farmer is a relatively wealthy farmer considering that he sells tea and bananas, keeps crossbreed instead of local cows, is self-sufficient in fodder production and applies mineral fertilizers. However, his total farm size is comparably small (Tittonell 2008). For the assessment of the profitability of 'business as usual' as well as improved farm management practices, current market prices for products, inputs and labour were collected in Vihiga County in September 2015. At the time of this market evaluation, KES 100 was equal to approximately USD 1; the bank interest rate was 20 percent; depreciation on infrastructure 9 percent; and operation, maintenance and insurance 5 percent. It was assumed that the farm-household would spend KES 3750 per year per animal for healthcare.

3. Results & Discussion

Baseline comparison between the Kenyan and the Ethiopian farm

The Ethiopian farm has more root biomass and stubble (1129 kg SOM ha^{-1}) than Kenya due to higher inputs and yields. It also has a positive SOM balance of 819 kg ha^{-1} at field level due to biomass retention (20%), unlike Kenya whose SOM balance is negative (-75 kg ha^{-1}). The Kenyan farm generally has more manure hence more SOM (2526 kg SOM ha^{-1}) due to higher livestock density than the Ethiopian farm. Manure degradation in the Kenyan farm is also much faster (2279 kg SOM ha^{-1}) due to wetter and hotter climate than in the Ethiopian context (Table 1).

The Kenyan farm is losing carbon (C) at a very slow rate (Figure 2); most of the carbon is lost through respiration (1096 kg C ha^{-1} from the household and 2359 kg C ha^{-1} from the animals) due to a much higher livestock density than the Ethiopian farm. The Kenyan farm also has a higher carbon flow from crops to livestock (4351 kg C ha^{-1}) because all the residue is fed to the livestock, as well as a higher carbon flow from manure to the soil (1263 kg C ha^{-1}) as a larger amount of manure is deposited due to a higher livestock density compared to the Ethiopian farm. There is also a higher manure degradation rate (821 kg C ha^{-1}) on the Kenyan farm – a result of the hotter and wetter climate as mentioned earlier.

		Ethiopia kg ha^{-1}	Kenya kg ha^{-1}
Inputs			
	Root biomass and stubble	1129	578
	Surface residue retention	185	0
	Own manure	1114	2526
	Imported manure	0	0
Outputs			
	Manure degradation	956	2276
	SOM degradation	653	903
	Erosion losses	0	0
	Balance	**819**	**-75**

Table 1: Baseline soil organic matter balance at field level (kg ha^{-1}) of the Ethiopian and Kenyan farms

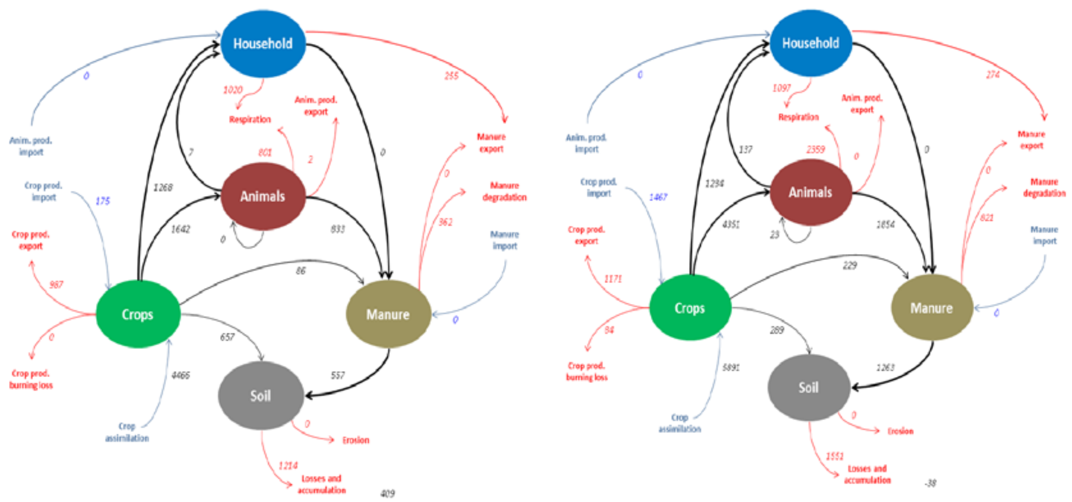

Figure 2: Baseline farm C cycles (kg C ha^{-1}) for the Ethiopian farm (left) and the Kenyan farm (right)

		Ethiopia kg ha^{-1}	Kenya kg ha^{-1}
Inputs	Import crop products	6	39
	Import animal products	0	0
	Import manure/fertilizers	244	33
	Fixation	11	22
	Deposition	5	5
	Non-symbiotic fixation	5	5
Outputs	Export crop products	40	120
	Export animal products	1	0
	Export animal manure	0	0
	Export of household excreta	46	65
Balance			
	Inputs	271	104
	Outputs	87	185
	Balance	**184**	**-81**

Table 2: N flows and balance at farm level (k N ha^{-1})

More nitrogen (N) is imported into the Ethiopian farm (244 kg N ha^{-1}) than the Kenyan farm resulting from higher N fertilizer application on crop fields (Table 2). More nitrogen is exported from the Kenyan farm (120 kg N ha^{-1}) due to high biomass removal of tea and the negative nitrogen balance from the Kenyan farm (-81 kg ha^{-1}) indicates nutrient mining because removal exceeds the supply. Nutrient depletion is a major form of land degradation in mixed crop-livestock systems, and nutrient balances are often negative (Stoorvogel et al. 1993). Areas of high population density and therefore diminishing farm sizes represent the most severe cases of ongoing deterioration of soil fertility, which is causing progressive impoverishment (Shepherd and Soule 1998).

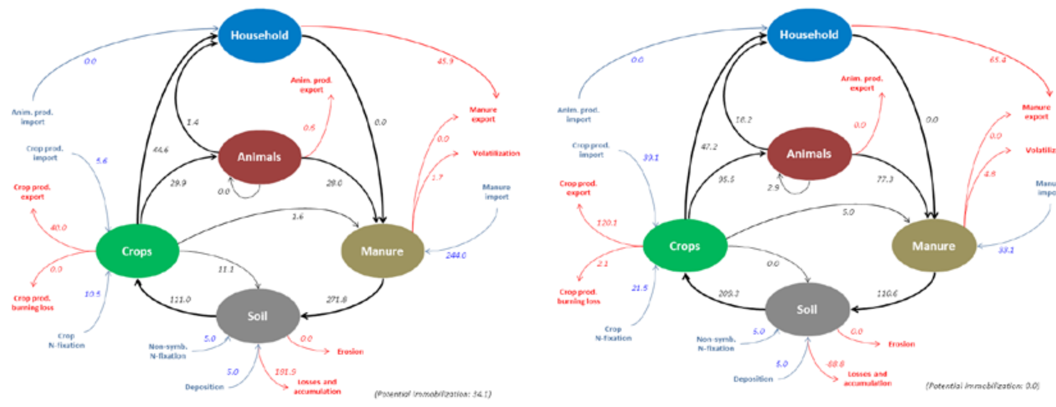

Figure 3: Baseline farm N cycles (kg N ha^{-1}) for the Ethiopian farm (left) and the Kenyan farm (right)

There is a larger nitrogen flow from livestock to the household on the Kenyan farm (18 kg N ha^{-1}) resulting from more milk and meat consumption by the Kenyan household than the Ethiopian household (Figure 3) which has a much lower nitrogen flow (1.4 kg N ha^{-1}) into the household from livestock. There is also a larger nitrogen flow from crops to animals in the Kenyan farm (95.5 kg N ha^{-1}) than in the Ethiopian farm (29.9 kg N ha^{-1}) due to high crop residue intake by the animals. The Ethiopian farm has more nitrogen going into soils due to higher nitrogen fertilizer application on crop fields as well as more nitrogen imported through fertilizer bought from outside the farm. The flow of nitrogen from livestock to manure is also larger since most manure is produced on the farm. In the Kenyan farm more nitrogen is lost to volatilization (4.8 kg N ha^{-1}) due to lack of proper manure management.

Scenario assessment for western Kenya

In addition to assessing business-as-usual farm management and related organic matter, N fluxes and balances, we tested some potential management practices that explicitly address either soil fertility management or intensifying livestock production.

The first set of scenarios tested various management practices related to soil (input) management, constituting components of Conservation Agriculture (CA) and Integrated Soil Fertility Management (ISFM).

1. **Zero-tillage (ZT)**: Conventional tillage is known to increase the decomposition of organic matter in the soil. Thus, in response to not disturbing the soil, we decreased the annual SOM degradation rate from 3.5 percent to 2.5 percent. Unless herbicides are applied, often the labour demand for weeding increases under ZT. To account for this we increased the labour demand by 100 percent to 1400 h ha^{-1}. As crops are planted manually, zero-tillage does not entirely eliminate the time for land preparation/ seeding, and therefore we assumed that 50 percent less time is needed for tillage/ land preparation i.e. not more than 700 h $year^{-1}$.
2. **Inorganic fertilizer:** ISFM foresees a judicious (but often increased as compared to business-as-usual) use of mineral fertilizer. Therefore, we increased fertilization of tea from 90 to 150 kg N ha^{-1}, and that of maize, bean and Napier from 15 (Napier 0) to 40 kg N ha^{-1}. Labour changes were only made to the maize-bean field – 25 percent of labour on tillage, +50 percent on weeding.
3. **Mulching**: Retaining organic matter in the field is a crucial component of ISFM. Therefore, either 30 percent (1.9 t ha^{-1}, 'Mulching [a]'), or 50 percent (3 t ha^{-1}, 'Mulching [b]') of maize stover is left on the field, and the rest is still fed to the livestock. Green maize is still all fed to livestock. All bean residues (0.4 t ha^{-1}) are left on the field and no longer fed to the livestock. The feed balance is left untouched.

		Baseline	Zero-tillage	Inorganic fertilizer	Mulching (a)	Mulching (b)
		------------------------ (kg ha^{-1}) ------------------------				
Inputs						
	Root biomass and stubble	578	578	578	578	578
	Surface residue retention	0	0	0	94	146
	Own manure	2526	2524	2524	2287	2129
	Imported manure	0	0	0	0	0
Outputs						
	Manure degradation	2276	2275	2275	2061	1918
	SOM degradation	903	645	903	903	903
	Erosion losses	0	0	0	0	0
Balance		**-75**	**182**	**-76**	**-5**	**32**

Table 3: Baseline and ISFM scenarios SOM balance (kg SOM ha^{-1}) for the western Kenya farm

High level mulching (50% of residue) is the only form of mulching that can result in a positive SOM balance as shown in Table 3 whereby SOM balance is 32 kg SOM ha^{-1} in the 'mulching (b)' category, with a higher retention of organic matter in the crop fields. Unfortunately that level of mulching is often not feasible for livestock keepers; livestock in this scenario is more likely underfed as most of the residue goes to mulching as opposed to animal feed. Zero-tillage also results in a positive SOM balance but based on the assumption that it effectively decreases SOM decomposition.

		Baseline	Zero-tillage	Inorganic fertilizer	Mulching (a)	Mulching (b)
		------------------------ (kg/ha) ------------------------				
Inputs	Import crop products	39	39	39	39	39
	Import animal products	0	0	0	0	0
	Import manure/fertilizers	33	33	58	33	33
	Fixation	22	22	22	22	22
	Deposition	5	5	5	5	5
	Non-symb. fixation	5	5	5	5	5
Outputs						
	Export crop products	120	120	120	120	120
	Export animal products	0	0	0	0	0
	Export animal manure	0	0	0	0	0
	Export of household excreta	65	65	65	65	65
Balance						
	Inputs	104	104	129	104	104
	Outputs	185	185	185	185	185
	Balance	**-81**	**-81**	**-56**	**-81**	**-81**

Table 4: Baseline and ISFM scenarios nitrogen balance (kg N ha^{-1}) for the western Kenya farm

None of the ISFM scenarios results in a positive N balance (Table 4). All scenarios have more or less the same N balance result (-81 kg N ha^{-1}) apart from inorganic fertilizer application, which results in a less negative N balance (-56 kg ha^{-1}) though the levels are still too low.

4). The low returns from zero tillage are as a result of more labour costs for weeding which increases the expenses. Expenses also increase with purchase of inorganic fertilizers hence the lower returns as compared to mulching and the baseline.

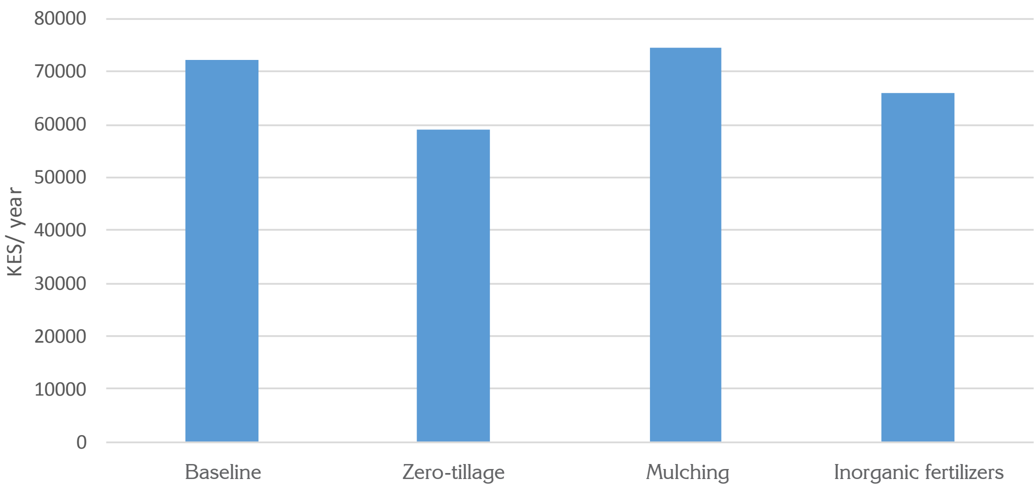

Figure 4: Operating profit in KES/year for ISFM scenarios for the western Kenya farm

Zero tillage is the ISFM scenario with the least returns (slightly less than 60 000 KES/ year) whereas returns from mulching are slightly higher than the other scenarios (Figure

More integrated livestock scenarios were designed to contrast with the impact of the pure ISFM scenarios before. The integration of crops and livestock production provides

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several advantages to smallholders, including diversified livelihoods, adaptive capacities to changing socio-ecological contexts and closer nutrient cycling (van Wijk et al. 2009).

1. **Better breed and feed:** The weight of two (now improved) cows is increased form 336 kg to 450 kg, and milk production per animal is doubled. More acreage is put under Napier production by decreasing the area of land under tea cultivation (0.05 ha of land converted). All Napier produced is fed to the cattle, and dairy cows are supplemented with purchased maize bran at 1 kg/day. Maize stover is no longer fed to the cows, but is left on the fields as mulch. However, livestock is still fed with green maize stover and some low quality roadside grass to complement the diet.
2. **More cows:** In scenario two, the weight of three (now improved) cows is increased from 336 kg to 450 kg, and milk production per animal doubled. There is no more tea production, as all that land has been converted into Napier fields. All Napier produced is fed to the cattle, and dairy cows are supplemented with maize bran at 1.6 kg/day. Maize stover is no longer fed to the cows, but is left on the fields as mulch. However, livestock is still fed with green maize stover and some low quality roadside grass to complement the diet.

Increase in livestock herd and substituting with better breeds in combination with providing better feeds are the only livestock intensification scenarios that result in a positive SOM balance, i.e. 222 and 175 kg SOM ha^{-1} respectively (Table 5). More surface crop residue can be retained (267 kg SOM ha^{-1}) as a result of providing substituting crop residue with Napier, hence providing better feeds. Increasing the herd size results in more manure production (3668 kg SOM ha^{-1}) and so does improved cow breeds that are better fed which means more organic matter inputs into soils.

Increasing herd size and ensuring they are well fed is the only livestock intensification

		Baseline	Better breed and feed	More cows
Inputs				
	Root biomass and stubble	578	568	495
	Surface residue retention	0	267	267
	Own manure	2526	2459	3668
	Imported manure	0	0	0
Outputs				
	Manure degradation	2276	2216	3305
	SOM degradation	903	903	903
	Erosion losses	0	0	0
Balance		*-75*	**175**	**222**

Table 5: Baseline and livestock intensification scenarios SOM balance (kg ha^{-1} year^{-1}) for the western Kenya farm

		Baseline	Better breed and feed	More cows
Inputs	Import crop products	39	66	77
	Import animal products	0	0	0
	Import manure/fertilizers	33	22	11
	Fixation	22	22	22
	Deposition	5	5	5
	Non-symbiotic fixation	5	5	5
Outputs				
	Export crop products	120	58	0
	Export animal products	0	17	34
	Export animal manure	0	0	0
	Export of household excreta	65	65	65
Balance				
	Inputs	104	120	120
	Outputs	185	140	99
	Balance	**-81**	**-20**	**21**

Table 6: Baseline and livestock intensification scenarios nitrogen balance (kg N ha^{-1}) for the western Kenya farm

scenario that results in a positive N balance i.e. 21 kg ha^{-1} (Table 6). Nitrogen is also imported from outside of the farm through concentrates. Through less or no cultivation of tea, the N export (through sale of tea which is a cash crop) decreases and diminishes as shown under the 'more cows' scenario (Table 6) where exportation of crop products is 'zero'. All livestock scenarios vastly improve operating profit (Figure 5), with increases by more than KES 6000 for 'better breeds and better feeds' and by more than KES 8000 for 'more cows'. Due to the low price of tea and high price of milk, it becomes more profitable to grow Napier instead of tea as Napier not only produces feed for livestock thus increasing milk production but can also be grown as a cash crop, despite the increased expenses on external feed. Under the current high prices for milk and low prices for tea, investing in livestock is profitable for a farmer, and this is reflected in experiences from the field. This is sometimes in detriment to the cattle because farmers may sell off Napier for quick cash instead of feeding it to their cattle, leaving their immediate cash needs fulfilled, and their cattle's bellies unfilled.

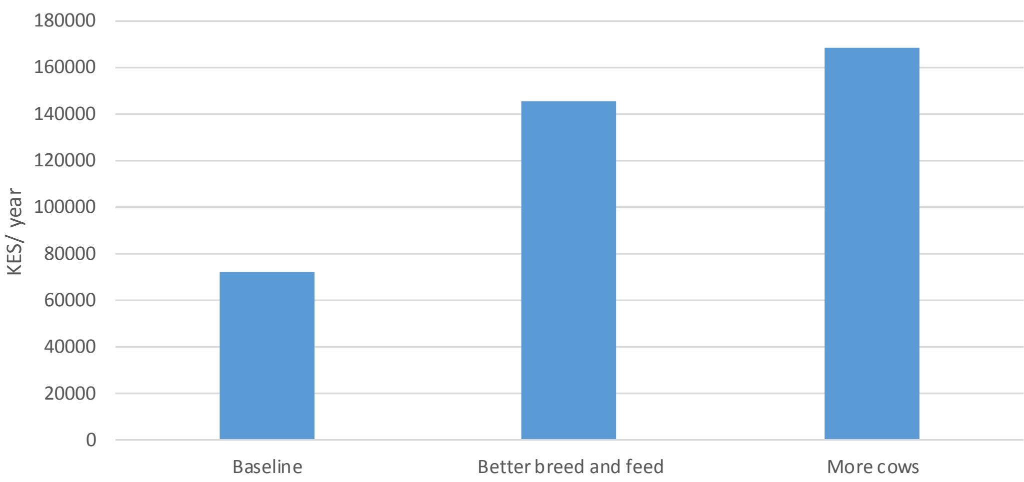
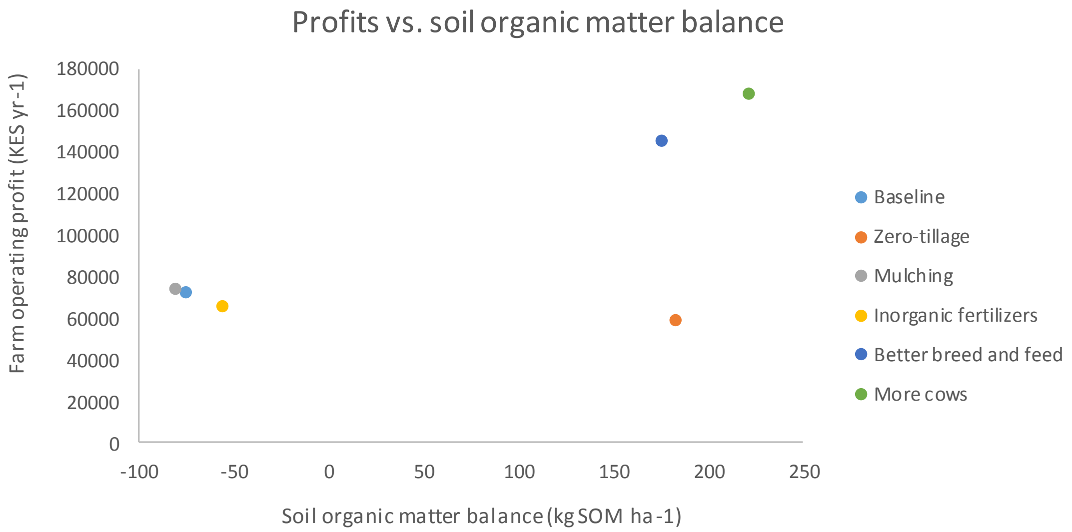


Figure 5: Operating profit in KES/year for livestock scenarios for the Western Kenya farm



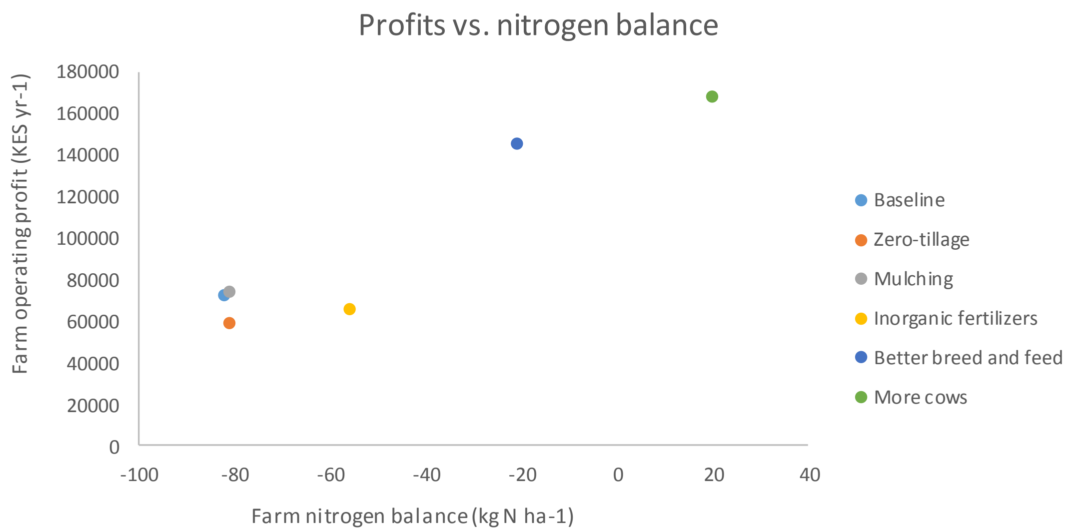


Figure 6: Trade-offs between operating profit and SOM balance (above) and operating profit and N balance (below)

Only livestock scenarios, i.e. more cows and better breeds that are better fed produce the least trade-offs when it comes to increasing operating profits and nitrogen balance, thus the most effective when it comes to producing the highest synergies between C, N and profits.

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Conclusions

This 'what-if' scenario analysis was conducted to support GIZ in designing their new soil development program. Comparing the baseline performance of the two contrasting farms in Kenya and Ethiopia illustrated that sustainability highly depends on climate (degradation rate), livestock pressure, commercialization and input use. Farming systems in Sub-Saharan Africa are heterogeneous, and so are their performance and entry points for improvement. The tested interventions have very different effects on the environmental dimensions of SOM, C and N. Improving breeds and increasing livestock numbers are good strategies for improved nutrient cycling such as N, but less for SOM since C in residues fed to livestock is readily lost through their respiration (CO_2) and enteric fermentation (CH_4). On the other hand, tillage and mulching interventions are crucial for improved SOM, but do not affect nutrient balances. This underlines that a combination of technologies is important to marry nutrient and SOM management. Moreover, there is a clear trade-off between feeding livestock and feeding the soil.

The study also revealed trade-offs between environmental and economic dimensions, which are central to lack of adoption of many natural resource management technologies. Mulching or zero tillage will not easily be adopted if it is not also profitable in the short term. This underlines again the importance of intervention packages instead of single interventions, especially in mixed crop-livestock systems where soil interventions need to integrate livestock. This study is to be seen as proof of concept that quantitative farm modelling can assess potential impact, thereby supporting decision-making, targeting, prioritization and program design. One of the next steps of this approach would be to take the diversity of farmers into account. Farm typologies and modelling of case studies for each is an effective mechanism for up-scaling results and making them relevant at a scale that organizations like GIZ work at. Participatory modelling, thus following of feedback loops between stakeholders and modellers, can greatly improve the quality and relevance of results.

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