Climate smartness of GIZ soil protection and rehabilitation technologies in Burkina Faso

CIAT Working Paper

The International Center for Tropical Agriculture (CIAT) – a CGIAR Research Center – develops technologies, innovative methods, and new knowledge that better enable farmers, especially smallholders, to make agriculture eco-efficient – that is, competitive and profitable as well as sustainable and resilient. Headquartered near Cali, Colombia, CIAT conducts research for development in tropical regions of Latin America, Africa, and Asia.

CIAT is proud to celebrate *50 years* of agricultural research and development impact

In 1967, the majority of poor and hungry people in the tropics were smallholder farmers. Increasing the productivity of their crops was, therefore, the critical entry point for CIAT's research. Since that time, we have been concerned with nearly every aspect of tropical agriculture: the crop varieties that farmers grow, the production systems they manage, the agricultural landscapes they inhabit, the markets in which they participate, and the policies that influence their options and decisions. Today, we also look forward at emerging challenges, with a renewed commitment to feed the planet and offer a better deal for both farmers and consumers.
www.ciat.cgiar.org

CGIAR is a global research partnership for a food-secure future. Its science is carried out by 15 Research Centers in collaboration with hundreds of partners across the globe.
www.cgiar.org

Climate smartness of GIZ soil protection and rehabilitation technologies in Burkina Faso

Rapid Assessment Report

Celine Birnholz, Špela Kalčić, Jessica Koge, Birthe Paul,
Juliet Braslow, Rolf Sommer, and An Notenbaert

CIAT 50 1967-2017

RESEARCH PROGRAM ON Water, Land and Ecosystems
CGIAR

Centro Internacional de Agricultura Tropical
International Center for Tropical Agriculture
Regional Office for Africa
PO Box 823-00621
Nairobi, Kenya
E-mail: b.paul@cgiar.org
Website: www.ciat.cgiar.org

CIAT Publication No. 430
January 2017

Birnholz C; Kalčić Š; Koge J; Paul B; Braslow J; Sommer R; Notenbaert A. 2017. Climate smartness of GIZ soil protection and rehabilitation technologies in Burkina Faso, Rapid Assessment Report. Working Paper. CIAT Publication No. 430. International Center for Tropical Agriculture (CIAT), Nairobi, Kenya. 32 p.

Celine Birnholz, research associate, Tropical Forages Program, Agrobiodiversity Research Area, based at CIAT-Kenya

Špela Kalčić, researcher, consultant based in Burkina Faso

Jessica Koge, research assistant, Tropical Forages Program, Agrobiodiversity Research Area, based at CIAT-Kenya

Birthe Paul, scientist | Tropical Forages Program, Agrobiodiversity Research Area, based at CIAT-Kenya

Juliet Braslow, scientist, Soils Research Area, based at CIAT-Kenya

Rolf Sommer, principal scientist, Soils Research Area, based at CIAT-Kenya

An Notenbaert, senior scientist, Tropical Forages Program, Agrobiodiversity Research Area, based at CIAT-Kenya

Photo credits: Peter Casier/CGIAR (cover photo); Ollivier Girard/CIFOR; Celine Birnholz.

Contents

Figures

Tables

Acknowledgements

This report is an output of the project ‘Climate-smart soil protection and rehabilitation in Benin, Burkina Faso, Ethiopia, India and Kenya’, led by the International Center for Tropical Agriculture (CIAT), with funding from the German Federal Ministry for Economic Cooperation and Development (BMZ) / Deutsche Gesellschaft fuer Internationale Zusammenarbeit (GIZ) under Contract # 81194110.

We warmly thank the workshop participants for their support, engagement and wealth of insights and information. We would also especially like to thank Gilbert-Honoré Zomahoun and Désiré Jean-Pascal Lompo from GOPA/AFC consulting group, Program Protection and Rehabilitation of Degraded Soils in Provinces of Houet and Tuy in Burkina Faso (ProSol/GIZ) for guiding and planning the workshop, assisting in identifying and inviting stakeholders, and organizing a post-workshop field trip; Cordula Schmüdderich (ProSol Coordinator Burkina Faso) for supporting our activities and participating in the workshop; Jean Marcel Oule (Regional Director of Agriculture), Chief Extension Officers Omar Dabonne (Technical Assistance/Extension Service Focal Point Karankasso-Vigué), Amado Sayore (Technical Assistance/Extension Service Focal Point Lena) and Boureima Belem (Technical Assistance/Extension Service Focal Point Koumbia) for participating in the workshop and arranging for the survey of specific households that are representative of the farm types across Tuy and Houet, identified during the Burkina Faso workshop.

Photo: Ollivier Girard (CIFOR)

Photo: Peter Casier (CGIAR)

1. Introduction

Burkina Faso is a landlocked Sahelian country challenged by low and variable rainfall and low agricultural potential. Historically, agriculture has been dominated by cotton production, the key cash crop. The non-cotton agricultural sector remains characterized by low yields, almost exclusive dependence on rainfall, and generalized underuse of modern production technologies (AGRA, 2014). So far, Burkina Faso's economic development is largely dependent on agriculture, with cotton being the main export product. The agricultural sector is a fundamental part of the economy, contributing about 30% to the total Gross Domestic Product (GDP) and occupying approximately 86% of active population (Burkina Faso, 2013). The sector provides 61.5% of agricultural households' cash revenues. About 67% of these revenues come from crop production, 31% from livestock and 2% from environmental products (Burkina Faso, 2011).

Globally, agriculture is a principal source of climate change, directly contributing 14% of anthropogenic GHG emissions, and another 17% through land use change; the latter mostly in developing countries. The majority of future increase in agricultural emissions is expected to take place in low- to middle-income countries (Smith et al., 2007). While industrialized countries must dramatically reduce current levels of GHG emissions, developing countries face the challenge of finding alternative, low carbon or green growth development pathways. In this sense, climate-smart agriculture (CSA) aims at transforming agricultural systems to sustain food security under climate change while also limiting GHG emissions. CSA is complementary to sustainable intensification (SI), aiming at increasing agricultural productivity from existing agricultural land while lowering the environmental impact. SI's focus on resource use efficiency and CSA's pillar on mitigation both focus on achieving lower emissions per unit output. Increased resource use efficiency contributes to adaptation and mitigation through increased productivity and reduced GHG per unit output (Campbell et al., 2014). Both, CSA and SI underline the importance of potential trade-offs between agricultural production and environmental degradation. In fact smallholder farmers are confronted with trade-offs almost on a daily basis. They have to weigh short-term production objectives against ensuring long-term sustainability and global goods such as climate change mitigation (Klapwijk et al., 2014). Although CSA aims at improving food security, adaptation and mitigation, it does not imply that every recommended practice should necessarily be a 'triple win'. Mitigation in developing countries is often seen as a co-benefit, while food security and adaptation are main priority. Low emission growth paths might have more associated costs than the conventional high emission pathways, thus monitoring can open opportunities for climate finance funds (Lipper et al., 2014).

The project 'Climate-smart soil protection and rehabilitation in Benin, Burkina Faso, Ethiopia, India and Kenya', was designed to build on CIAT's expertise in both soil science and CSA and to assess the climate-smartness of selected GIZ-endorsed soil protection and rehabilitation measures in the five countries. Soil rehabilitation is often evaluated for productivity and food security benefits, with little attention to climate smartness. Likewise, CSA initiatives have not given due attention to soil protection and rehabilitation, despite their apparently strong potential to increase climate-smartness. There is a need to align soil protection and climate-smart agriculture, in implementations of agricultural innovation practices that address soil degradation issues and climate change mitigation and adaptation. Thus the goal of the project is to produce detailed information on the climate smartness of ongoing soil protection and rehabilitation measures in these countries, identify suitable indicators for future monitoring and evaluation, as well as potentials to increase the climate smartness of these measures. This project contributes directly to the objectives of the BMZ-GIZ Soil program on 'Soil Protection and Rehabilitation for Food Security' as part of Germany's Special Initiative "One World – No Hunger" (SEWOH), which invests in sustainable approaches to promoting soil protection and rehabilitation of degraded soil in Kenya, Ethiopia, Benin, Burkina Faso and India. It furthermore supports policy development with regard to soil rehabilitation, soil information and extension systems. The climate-smart soil protection and rehabilitation research project allows GIZ to widen the scope of soil protection and rehabilitation for food security by aligning with the goals of climate-smart agriculture.

This report focuses on the results from the first activity of the project. The objective of the rapid assessment of climate-smartness of GIZ endorsed soil rehabilitation and protection technologies in Burkina Faso, is to evaluate these technologies in terms of their potential impact on productivity, nitrogen (N) balances, erosion, and greenhouse gas (GHG) emissions. These are suitable (rapid) indicators representing the three CSA pillars – food security, adaptation and mitigation.

During a participatory workshop in Bobo-Dioulasso, 4 distinct farming types were identified in the Burkinabe provinces Tuy and Houet (Kalčić and Birnholz, 2016). Subsequently, household interviews were conducted in farm households that were deemed representative of the 4 farm types identified during the workshop. The data collected on these farms forms the basis of the baseline calculations for the indicators mentioned above. The soil technology scenarios were derived during workshop discussions, and complemented by data from technical documents of GIZ and implementing partners, so as to reflect practices promoted in Tuy and Houet as closely as possible. In sections 2 and 3 we provide more details about the methodology and the sampled farms. Descriptions of the implemented soil rehabilitation scenarios are described in section 4, while results are presented in section 5, and conclusions/ recommendations in section 6.

2. Methodology

Following the participatory workshop that identified 4-6 farming system types per country, potential representative farms were jointly identified by CIAT, GIZ and ministry staff for a rapid assessment. The rapid assessment is based on a case study approach thus only one farm per type was selected and sampled. The head of the household was interviewed and household data collected using a questionnaire similar to that used within IMPACTlite (http://bit.ly/2h3KAZf). Information about crops and livestock was collected including data about plot sizes, yields, use of crop products and crop residues, labour activities and inputs. Similar information was gathered for the livestock activities if any. In some cases, soil samples were taken from different plots.

The data collected served as input for the model used for the rapid assessment. The rapid assessment model, named Kalkulator, calculates the following indicators according to different methodologies:

Productivity: Farm productivity was calculated based on the energy (calories) produced on farm – crop and livestock products – and compared to the energy requirement of an adult male equivalent of 2500 k cal per day (AME). Energy from potential direct consumption of on-farm produce was calculated by multiplying the energy content of every crop and livestock product with the produced amount. It is thus important to note that the indicator simply represents on-farm food/energy production, not the actual consumption, which should be taking into account additional food purchases and subtract the produce that is sold. Energy contents were based on a standard product list developed by the US Department of Agriculture USDA (source: http://bit.ly/1g33Puqt). The total amount of energy produced on the farm was then divided by 2500 kcal to obtain the number of days for which 1 AME is secured. For the sake of cross-farm comparability, these data were then also expressed on a per-hectare basis.

Soil Nitrogen balance: This balance was calculated at the plot level following the empirical approach of NUTMON as described in Van den Bosch et al. (1998). The following soil N-inputs were considered i) mineral fertilizers, ii) manure, iii) symbiotic fixation by legume crops, iv) non-symbiotic fixation, and v) atmospheric deposition. The N-outputs are i) crops and residues exported off the field, ii) leaching of nitrate, iii) gaseous loss of nitrogen (NH_3 and N_2O) and iv) soil erosion.

For calculating N inputs from manure and fertilizer, and N outputs from crop and residues, farmer reported data on quantities from the household survey was used. For N inputs from N fixation and deposition as well as N outputs from leaching, gaseous losses and soil erosion, transfer functions were used that are based on the rainfall and soil clay content of the specific site.

The N balance is calculated for each plot (kg N/plot) and then summed to obtain the farm-field balance expressed in kg N per farm. These results are then, again, converted into kg N per ha.

Soil erosion: Soil erosion is calculated at plot individual field level following the Revised Universal Soil Loss Equation (RUSLE; Renard et al., 1991; Amdihun et al., 2014).

Soil loss (t/ha/year) = R*K*LS*C*P

where,

R = Erosivity factor (a function of rainfall in mm/month)

K = Erodibility factor

LS = Slope length factor (function of the length and gradient of the slope)

C = Crop cover factor (function of the crop type)

P = Management factor (function of agricultural management practices).

Further information on each factor can be found at: www.iwr.msu.edu/rusle/factors.htm

GHG emissions: The GHG emissions are calculated at farm level following the guidelines of the International Panel on Climate Change (IPCC, 2006). Emissions from livestock (methane from enteric fermentation), manure (methane and nitrous oxide), and field emissions (nitrous oxide) are taken into account as illustrated in the graph below. Household survey data on livestock feed, livestock numbers and whereabouts, manure and fertilizer use, crop areas, and residue allocation was used as input data for the calculations. Most of the calculations follow IPCC Tier 1 methods, while Tier 2 calculations were performed for enteric fermentation and manure production (Figure 1).

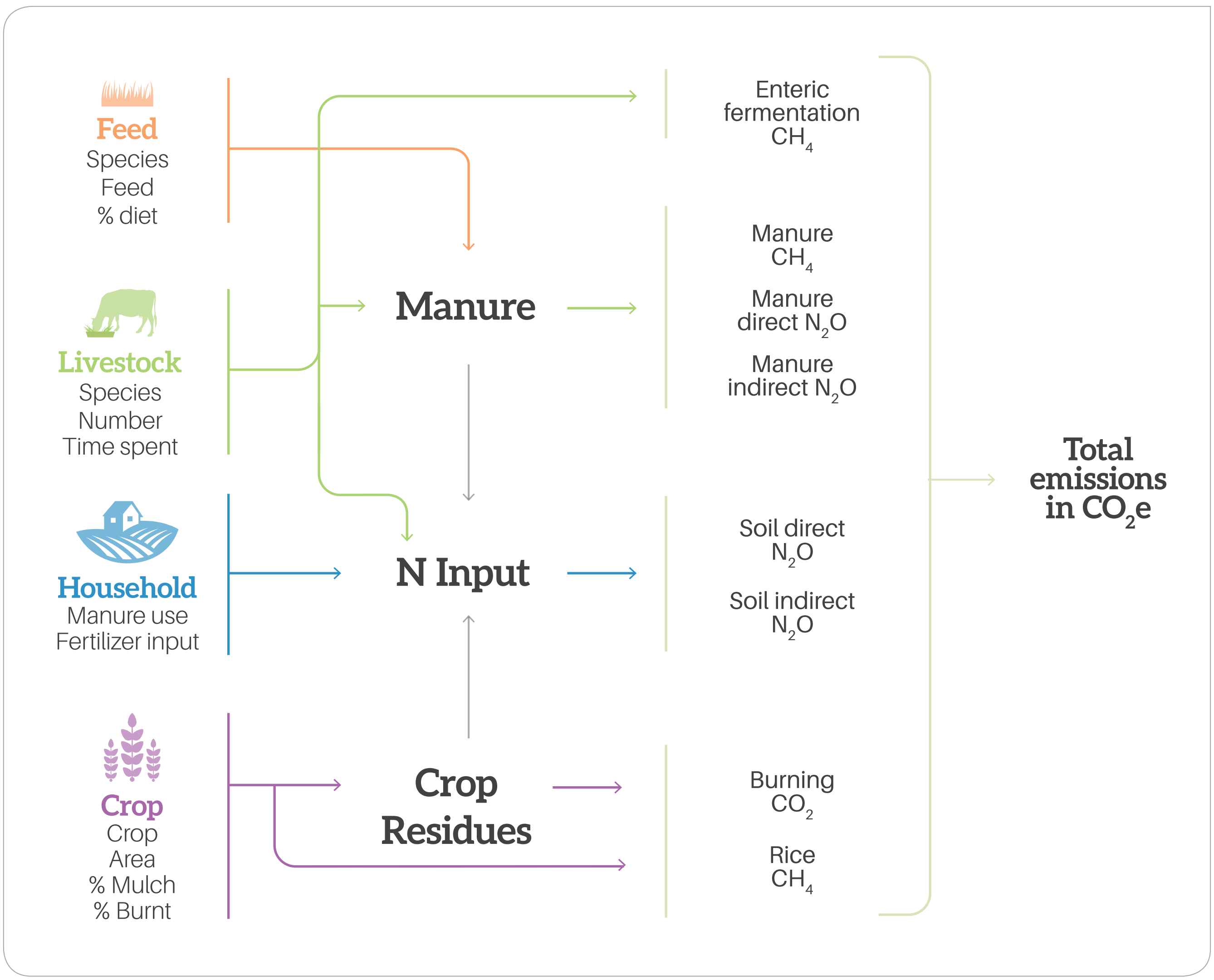


Figure 1. Scheme of the GHG emission calculations.

3. The case study farms

A participatory workshop was organised in Bobo-Dioulasso to describe and classify the farms of the ProSOL intervention sites (Kalčić and Birnholz, 2016). Workshop participants, invited for their expertise of the farming systems and working with farmers in the sites, included representatives from GIZ, GOPA/AFC ProSOL consulting group, Ministry of Agriculture, Water Resources, Sanitation and Food Security (MARHASA), National Institute for Environment and Research in Agriculture (INERA), Multipurpose Agricultural Center (CAP-Matourkou), Textile Fibre Company SOFITEX and CIAT. Four farm types were identified during the workshop: (1) large-scale/modern farms, (2) medium-scale/semi-modern farms, (3) small-scale/traditional/manual farms and (4) small-scale/traditional/manual farms managed by a woman or a young man. Kalčić and Birnholz (2016) provide a detailed description of these four farm types. Reference maps produced for the workshop mapping soil and climate characteristics of the study sites can be found in Appendix III. It should be noted that the debate on percentage of households that fall within each type was not concluded. In regards to distribution of different farming systems in the two provinces, participants agreed that the percentage of households that fall within each type is the same. There was a consensus that large farms are less numerous. However, participants did not reach a common understanding on the percentage of small- and medium-scale farms, but agreed that the medium-sized farms are the most numerous among farm households.

After the workshop – and with the help of GOPA/AFC ProSOL consulting group and extension officers from the MARHASA Provincial Extension Services – one representative case study farm was selected for each of the farm types. The case study farmer for the small scale was selected in the commune of Lena (Houet), the medium-scale farmer was selected in Karankasso-Vigué (Houet) while a large-scale farm and a small-scale female-headed farm representative were selected in the commune of Koumbia (Tuy; Figure 2). These farms were visited and detailed information was collected for the use as input data to model GHG emissions, nitrogen balance, erosion and farm production.

One case study farm was selected for each of the farm types. The farms chosen were typical farms that could be used as a representative of the farmers within each farm type. These farms were visited and detailed information was collected for the use as input data to model GHG emissions, nitrogen balance, erosion and farm production.

1. **Large-scale / Modern farm:** This farm has 24 ha, of which 20.5 is cultivated. The farmer has good financial assets and therefore access to draught power. He has about 17 local cattle, some sheep, pigs and poultry. Crop production is market-oriented, with maize and cotton as main crops. Other crops grown are rice, cowpea and

groundnut. Cotton production dominates, and is rotated with the other crops. Input use is relatively high on this farm.

2. **Medium-scale / Semi-modern farm:** The total land area of the farm, 7 ha, is cultivated. Crops grown include maize, sorghum, cotton, cowpea and groundnut. Household production in this farm has a dual purpose, i.e. for home consumption and for sale. The input use is slightly lower than on the large-scale farm. Also yields for maize and groundnut are lower than yields at large-scale farms; yields of cotton and cowpea, on the other hand, are higher. The farmer has a quite big herd of cattle and sheep, and also keeps some poultry.

3. **Small-scale / Traditional / Manual farm:** This type of farm has the smallest cultivation area; the sampled farm cultivates 3.25 ha. The production is mainly for subsistence (maize, sesame, cowpea, and groundnut); surplus produce is sold at the local market. The input use and yields are low. Small-scale farms usually do not keep cattle or sheep, but only around 40 heads of poultry.

4. **Small-scale / Traditional / Manual farm managed by a woman or a young man:** This small-scale farm is managed by a woman. She cultivates an even smaller farm of only 1.5 ha. She grows groundnuts and soybeans without input use and has therefore very low yields. This farmer does not own any livestock.

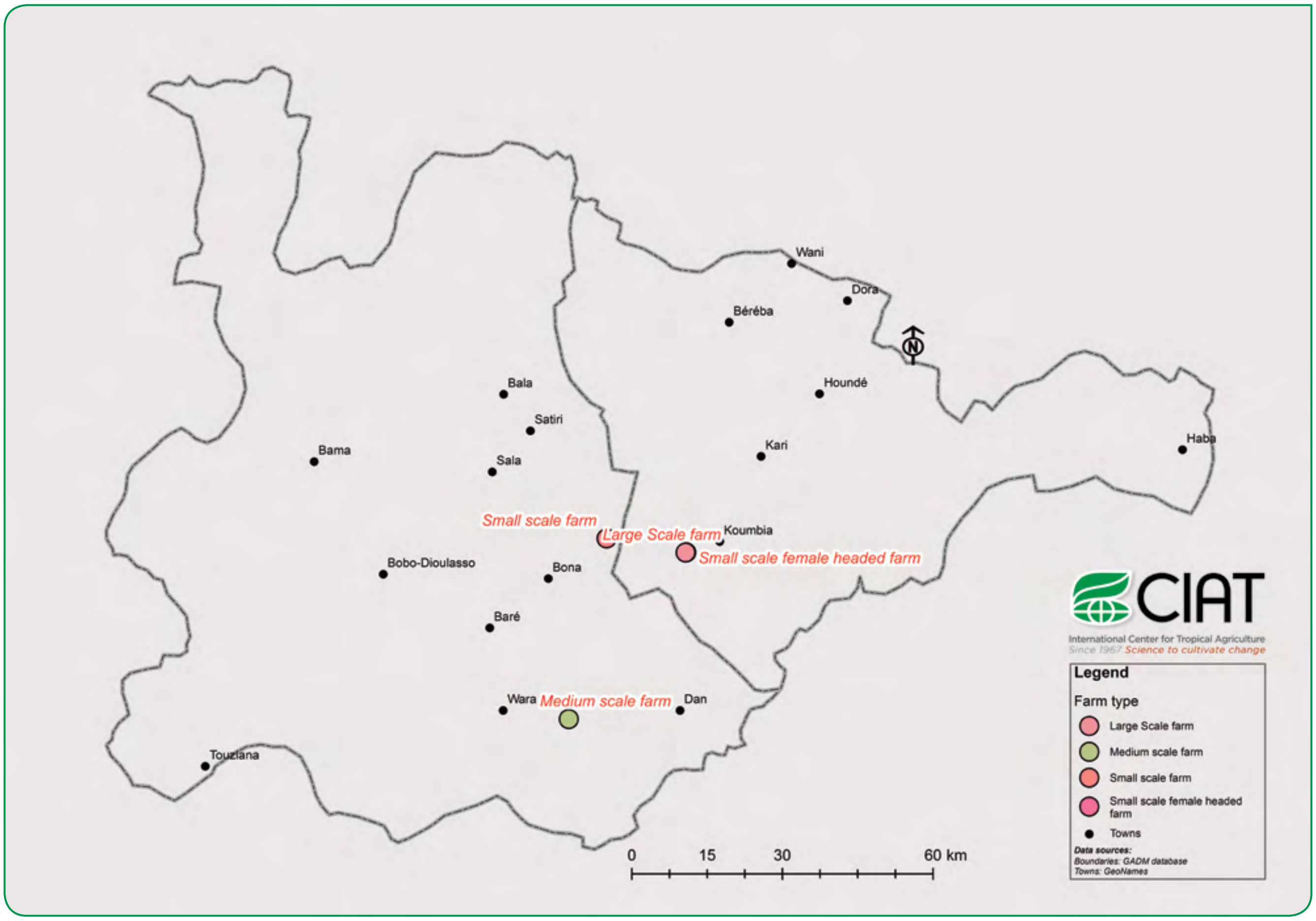


Figure 2. Location of case study farms in the Hauts-Bassins region.


Photo: Peter Casier (CGIAR)

4. Technology descriptions and scenarios

The following scenarios represent soil rehabilitation interventions that are currently promoted by GIZ in Burkina Faso or that are under discussion for future promotion. All assumptions are described according to impact dimensions and summarized in Appendix II Scenario Assumptions.

Stone bunds: This intervention is promoted to reduce soil erosion resulting from poor soil structure (insufficient rainwater infiltration) and intensive rains during the cropping season. This technology has been put in place in selected watersheds at landscape level. The bunds require space, namely approximately 10% of the land where they are implemented. This loss in crop area is, however, fully compensated by an increase in yield in response to better water capturing and reduced soil erosion/loss of topsoil fertility.

Composting with manure: Producing compost from crop residues and amending with manure is promoted to improve soil fertility. It is assumed that compost should be applied at a recommended rate of 5 t DM/ha. As compost is usually a limited good, only maize plots are fertilized with compost.

Intercropping of sorghum or maize with cowpea: Intercropping a cereal with cowpea is assumed to increase the overall productivity on the plot although yields of both crops are slightly lower in comparison to a mono-cropped stand, due to competition. Intercropping also reduces soil erosion because of improved soil cover.

Relay cropping with mucuna: On all farms but the female-headed one, mucuna is planted in relay in the maize plots providing N inputs to the soil for cotton that is cropped in the following season. At the same time the mucuna crop provides good soil cover to reduce erosion while also providing an extra source of feed for livestock, improving both the quantity and the quality of feed during the dry season resulting in higher milk yields.

5. Results

5.1 Productivity pillar

Farm productivity was calculated by summing up all the calories from crop and livestock products (except meat)[1] produced on farm and dividing this by the calorie requirements of an average adult (AME = Adult Male Equivalent) which is 2500 k cal/day. Productivity is thus expressed in numbers of AME days. Note that such productivity excludes food that is purchased as well as the possibility that produced food is sold and not consumed on-farm. As such, this indicator is not referring to the household's ultimate own food security but rather to its contribution to the overall food security.

5.1.1 Baseline productivity

Productivity is highest on the medium- and the large-scale farms with maize being the largest contributor to calories (Figure 3). Expressed on per ha basis, these farms have similar productivity providing enough kcal for about 2000 AME days. For these farms it is important to note that the production of cotton, which occupies a large area on the farms, does not produce directly consumable calories. Cotton production is, however, an important income earner. Legumes are the largest contributors to productivity on the two small-scale farms. The female-headed small-scale farm has a slightly higher productivity on a per hectare basis. Production of milk from livestock, as well as eggs do not contribute significantly to farm productivity, because livestock is raised extensively. However livestock is known to be an important means of resilience for farming households in Sub-Saharan Africa and thus must not be underappreciated towards contributing to household livelihoods. On the larger farms, cattle also contribute draught power, thus allowing farmers to cultivate larger tracts of land.

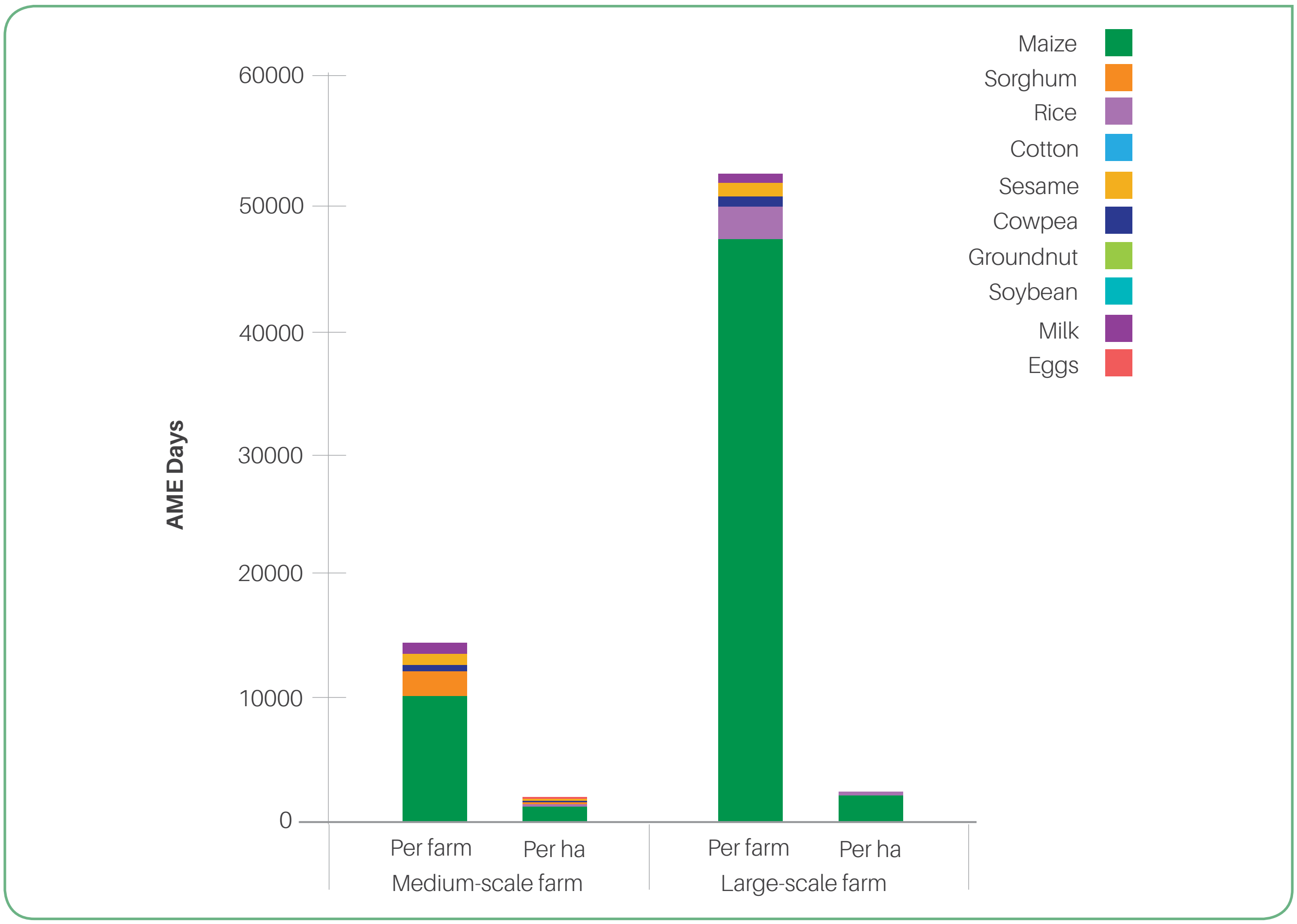
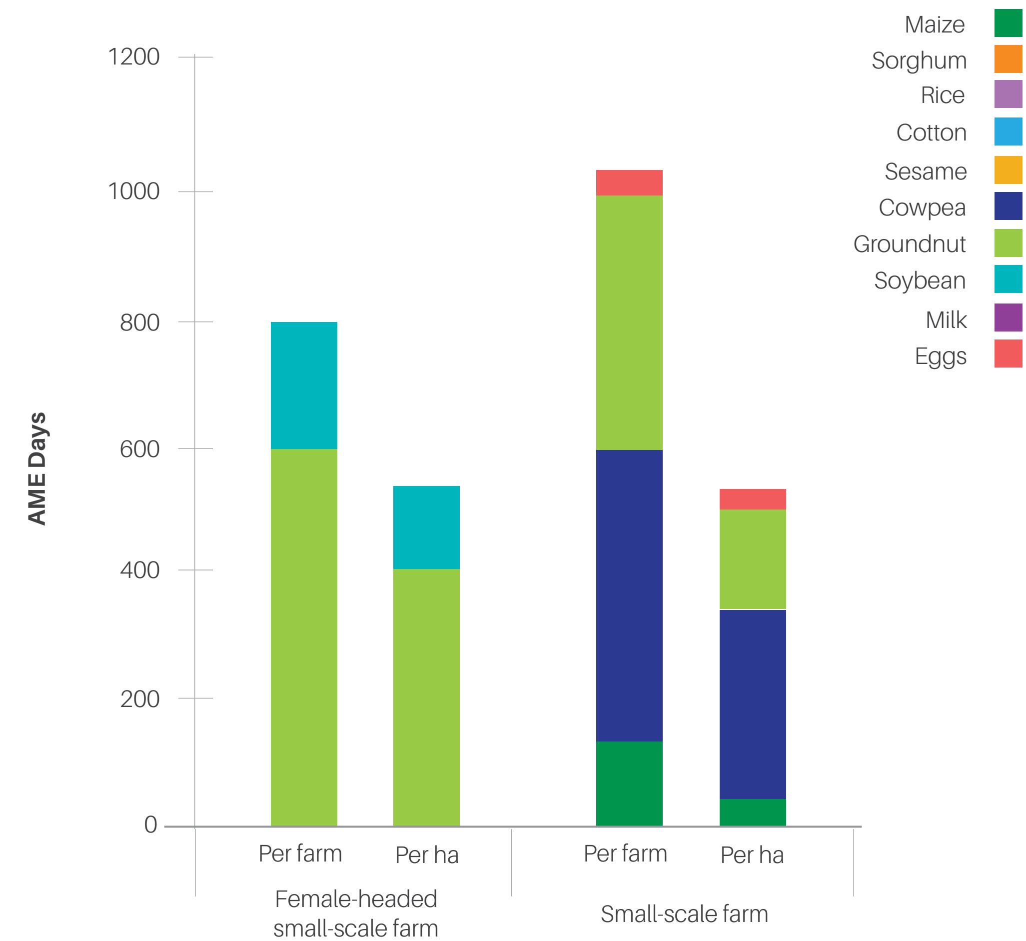


Figure 3. Baseline productivity and contribution from the different products across farm types. *Productivity is expressed as equivalents of number of days that 1 adult male (AME) can be fed from livestock and crop products produced on the farm.* (continues)

1 To be able to calculate production of meat from livestock, data on herd dynamics (offtake of animals per year) and impact of animal feed on livestock productivity are required, which were not available for this report.

(continued)



5.1.2 Changes in productivity

In most cases, introducing the various technologies described earlier (chapter 3) is projected to increase productivity across all farm types (Figure 4). This is mainly due to the increases in yields and in animal productivity that result from additional inputs of N, intercropping or from increasing the area of legumes (which have a high calorie content).

Stone bunds remove space available for cultivation but retain soil fertility thus we expect neither an increase nor decrease in productivity from this intervention. Composting with manure at the recommended rate of 5 t DM/ha is expected the have most impact on productivity across all farm types. Maize productivity increases because of the additional N-inputs from the compost. It is important to note that no limitation to compost availability was assumed as far as the area under maize is concerned. However, in reality, the availability of compost from the own farm will be limited and therefore the required additional compost must be purchased/imported. Intercropping cereals (sorghum and maize) with cowpea is expected to increase productivity even though crop yields of the two individual crops are reduced in comparison to mono-cropped conditions. This is the case in the female-headed small-scale farm. As the farm was already cropping cowpea, the intercropping scenario meant introducing sorghum to that field. The decrease in cowpea yields are compensated by the introduction of the new crop. On the other three farms, the introduction of cowpea to either the sorghum or maize plots increased productivity only little. Here, the anticipated reduction in the cereal yields (-20%) is barely compensated by the introduction of the legume crop. Yet, intercropping is beneficial, as far as crop and diet diversification is concerned. Planting mucuna as a green manure cover crop in relay with maize is done to improve soil fertility, as well as to provide soil cover. This results in an increase in cotton production, as cotton is planted after maize-mucuna. However, cotton production adds no calories. Yet, on the medium- and large-scale farms, mucuna crop residues are assumed to be grazed by livestock thus increasing livestock productivity. However since milk production contributes so little to the total farm calories, the increase in livestock productivity seems negligible at farm level.

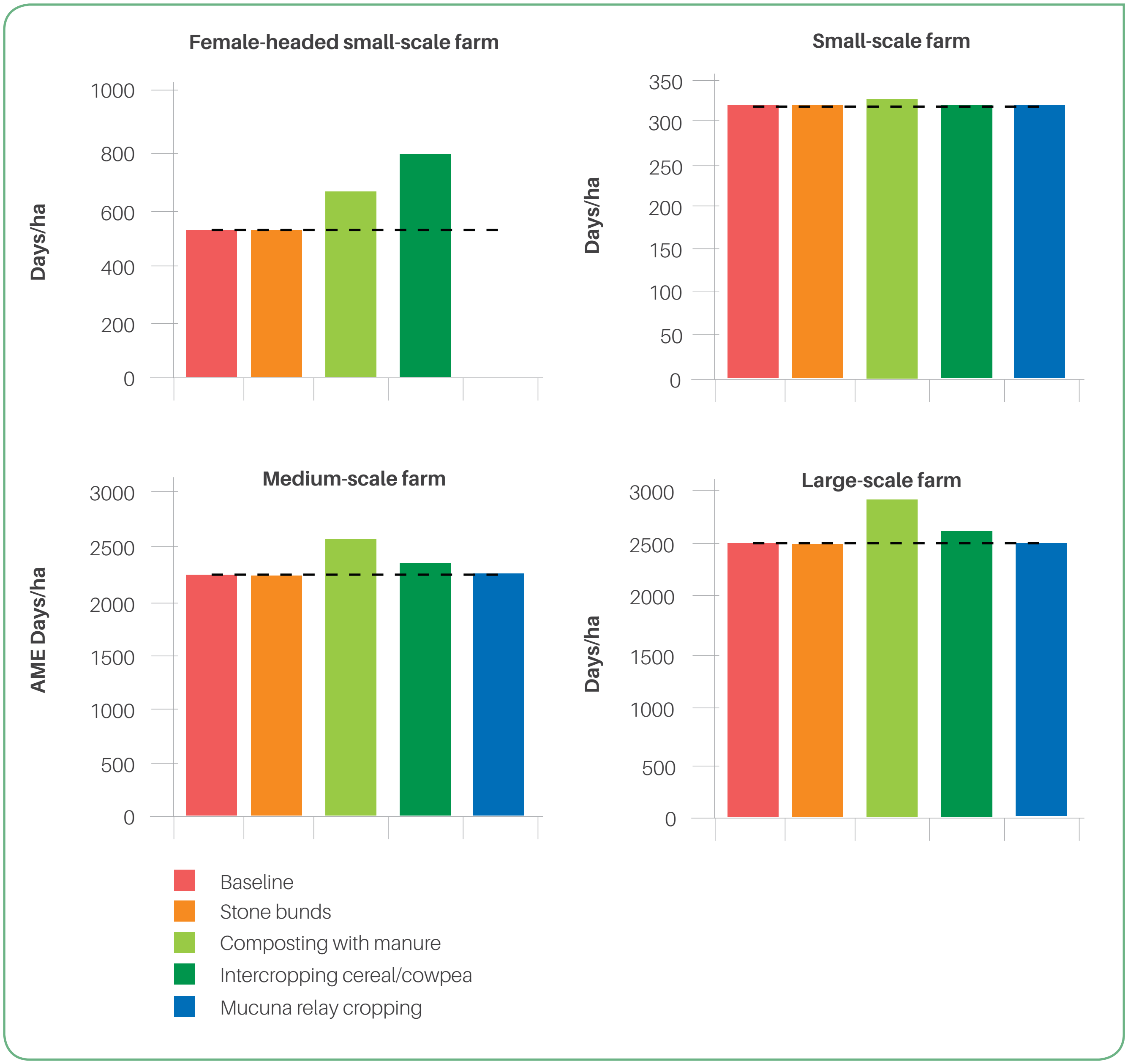


Figure 4. Baseline and scenario productivity per farm type. *Results are expressed in days of Adult Male Equivalent calories (AME = 2500 k cal/day) on a per hectare basis.*

5.2 Resilience pillar

Two parameters were selected as indicators to describe the resilience pillar of CSA: Nitrogen balance at field level, and erosion. The N balance is calculated for each of the fields found on the farm. The per-farm N balance is thus the sum of the N balances of all individual plots. Soil erosion is also calculated at individual field level and summed up for the whole farm. Reference is made to the appendix for further details on the calculations.

5.2.1 Baseline N balances

A negative N balance was calculated for all farms except the medium-scale farm (Figure 5). On the medium-scale farm, the positive N balance is due to inputs of N fertilizer to the maize fields. On all other farms N being exported from the fields in harvested crop products represent the biggest loss of N, as N inputs in the form of inorganic fertilizer, manure or compost are absent or too little to compensate for these withdrawals. Apart from maize and cotton production, all other crops are grown in an extensive manner (low input, low output). Therefore, the overall N-fluxes are comparably small, and the N balance per ha is close to 0 (ranging from -10 kg to +14 kg/ha). Nevertheless, this does not oppose the need for long term measures to increase the amount of N over time to counteract soil N depletion.

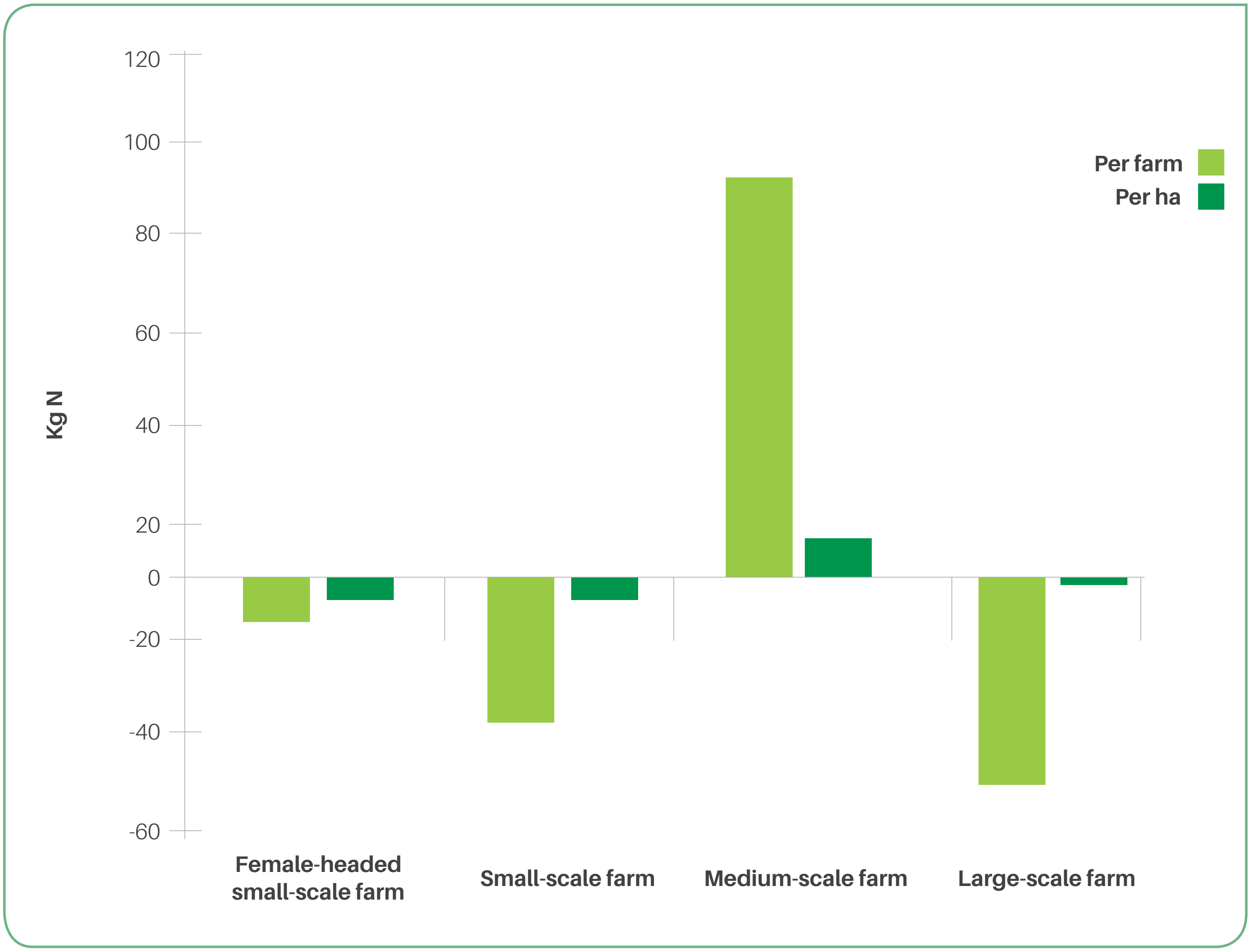


Figure 5. Baseline N balance at field level per farm and hectare across farm types.

5.2.2 Changes in N balance

Implementing the different technologies affects the N balance differently across farms (Figure 6). The N balance improves the least across interventions in the medium-scale farm because here N inputs through the interventions are not sufficient to replace the assumed decrease in the use of inorganic fertilizer. It is only the introduction of mucuna that overall will improve the N balance on the medium-scale farm. The addition of compost and manure impacts the N balance the most on the other farms, making it positive. This effect is expected to be largest on the female-headed small-scale farm, where yields remain relatively low and thus also the associated removal of N. However, it should be reiterated that this farm type has no livestock other than poultry, and that thus large quantities of manure or compost are not easily available. Intercropping with cowpea has a large negative effect on the N balance on both the medium- and large-scale farm despite the atmospheric N fixed by this legume. This is because this scenario simultaneously assumed a reduction in N-fertilizer application, while most of the fixed N is also exported via the harvested cowpeas. Relay cropping with mucuna improves the N balance across the three

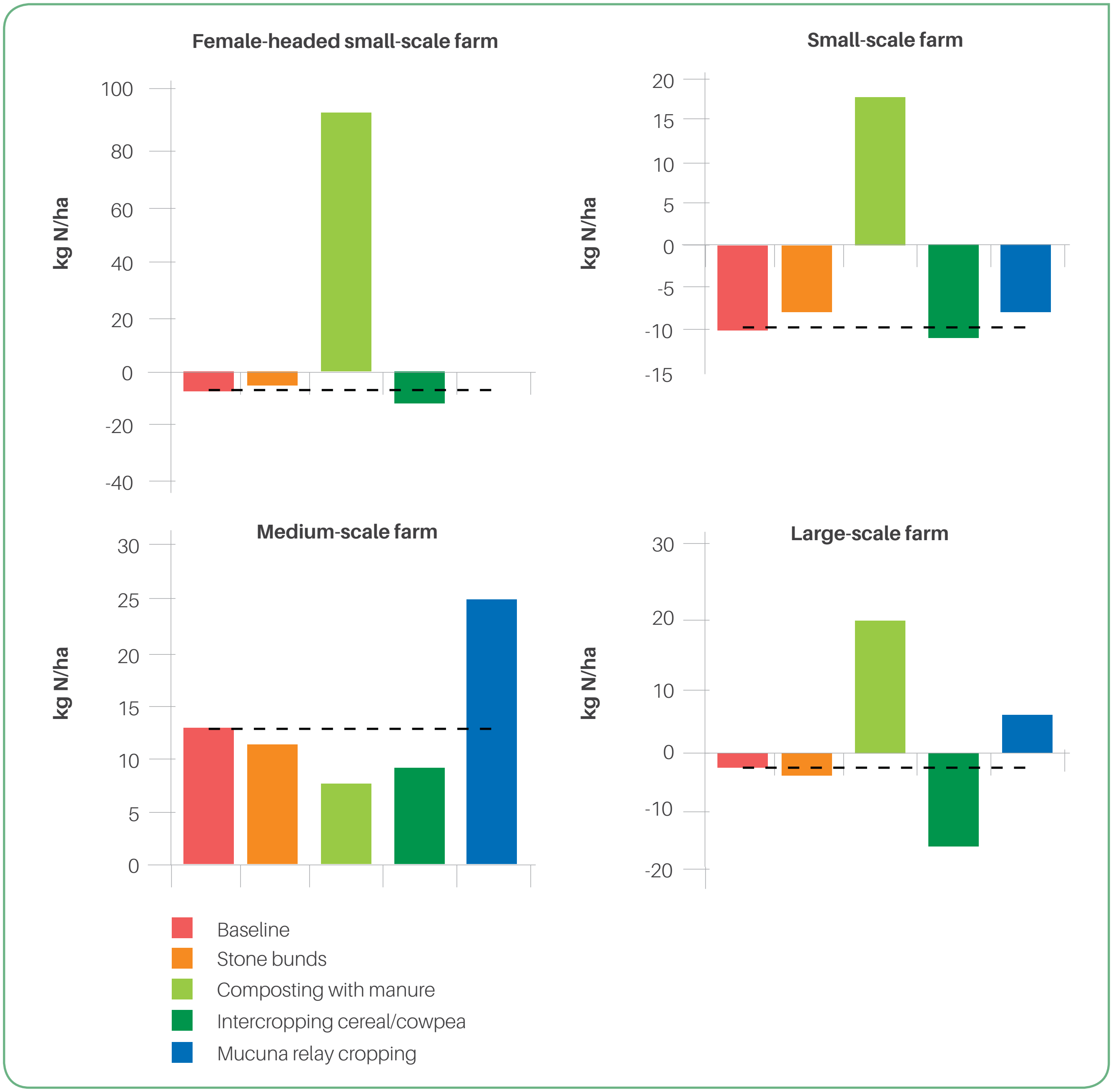


Figure 6. N balance of baselines and scenarios across farms (kg N/ha).

farms where it was implemented, mainly through the N fixation and the retention (part of) the crop from the fields.

5.2.3 Baseline erosion

Soil erosion is negligible with less than 5 t/ha/year across all farms (Figure 7), which is not surprising as all farms sampled were located on rather flat land. The difference in rainfall is what explains most of the difference in erosion rates apart from the different crop rotations on each farm. Indeed, rainfall is 170 mm less in the area where the medium-scale farm is located.

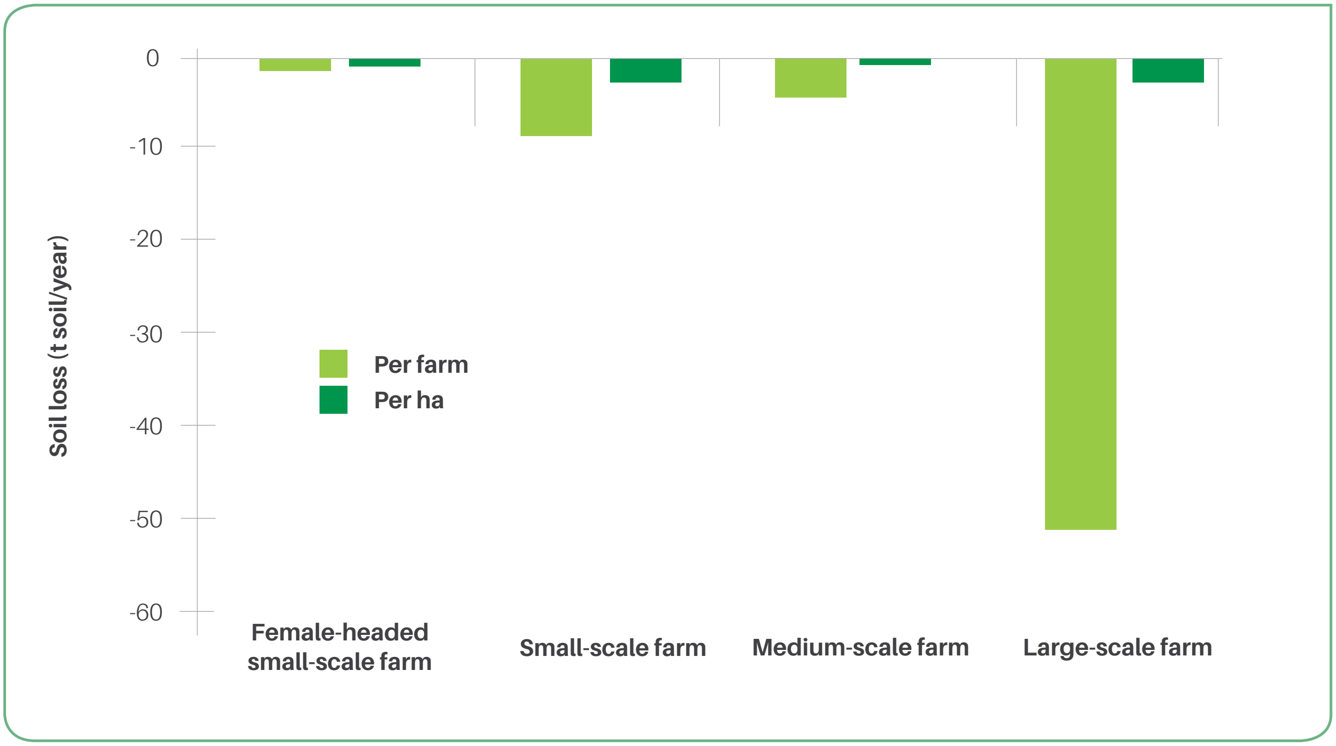


Figure 7. Baseline soil erosion (t soil/year), per farm or per hectare.

5.2.4 Changes in erosion

All interventions reduce soil erosion except for the compost/manure scenario (Figure 8). As expected, stone bunds impact soil erosion the most, not only because of the characteristics of the intervention, but also because of its scale (applied to all fields). Intercropping and relay cropping, if implemented, reduce erosion as well, but comparably less.

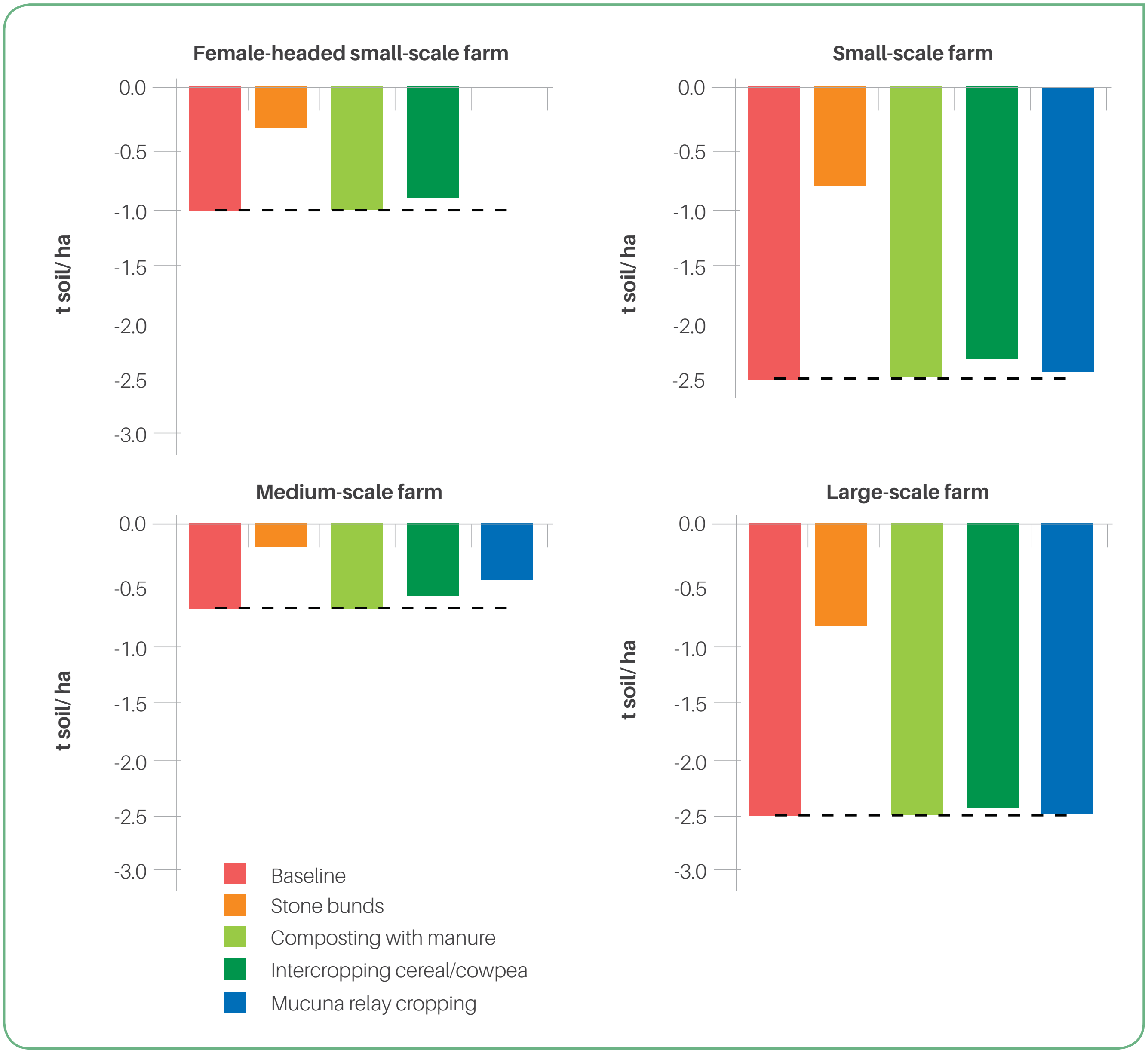


Figure 8. Soil erosion baselines and scenarios across farms (t soil/ha).

5.3 Mitigation pillar

The total GHG balance comprises emissions from enteric fermentation (methane), manure management (methane and nitrous oxide), soils (nitrous oxide and methane), and burning residues (carbon dioxide and methane). For easy comparison, these are converted into equivalents of carbon dioxide (CO_2e) and expressed per ha.

5.3.1 Baseline greenhouse gas emissions

Both small-scale farms have very low GHG emissions because of low input levels and little to no livestock production (Figure 9). On the medium and large-scale farms, emissions from livestock and from residue burning are the major contributors to the farm GHG emissions. Indeed, on both farm close to 40% of the area is under cotton cultivation, the crop residues of which are all burned. Per ha, the medium-scale farm has the highest GHG intensity, because of the higher livestock density compared to the large-scale farm.

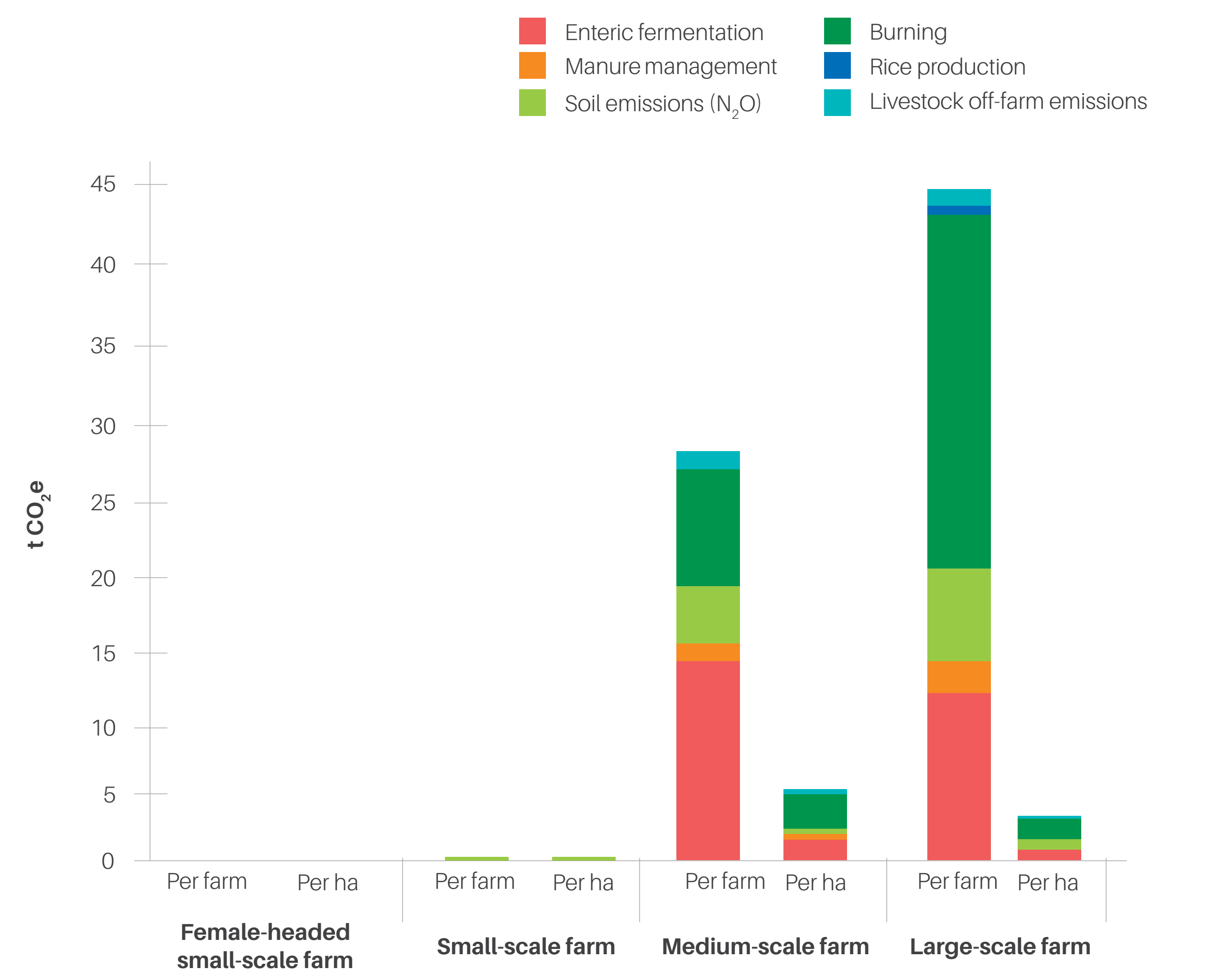


Figure 9. Baseline GHG emissions across farm types. *Emission sources include enteric fermentation, manure management, burning, rice production, off-farm livestock and soil emissions across farm types.*

5.3.2 Changes in GHG emissions

GHG emissions are affected by the interventions differently across the farm type (Figure 10).On the two small-scale farms, compost and manure application increase GHG emissions the most because of the extra nitrous oxide emissions from soils. Across the other interventions on the small-scale farms the GHG emissions increase only little because of the low level of inputs. Unlike on the small farms, the compost and manure intervention is associated with a decrease in GHG emissions on the medium- and large-scale farms. Although there is an input in N from additional compost/manure, there is also a reduction in the nitrous oxide emissions from soils due to reduced inorganic fertilizers. However, since most of the compost/manure has to be imported (to provide for the recommended application rates), the emissions from the production of this compost (elsewhere) are not counted for, while this is the case for compost produced on-farm. Thus, if the idea is to eventually produce all compost on-farm, it must be expected that emissions would increase above baseline levels, because of the amount of manure, and thus animals, required, as well as the GHG emissions during the composting process. Stone bunds reduce GHG emission the most on the large-scale farm. This is rather an artefact of the reduction of the maize plots (10 ha to 9 ha), which entails a reduction in mineral fertilizer required. There is a slight increase in GHG emissions in the mucuna relay scenarios. This is due to the increase in N coming from the crop residues on the fields. And the increased livestock productivity (more manure production) from better feeding.

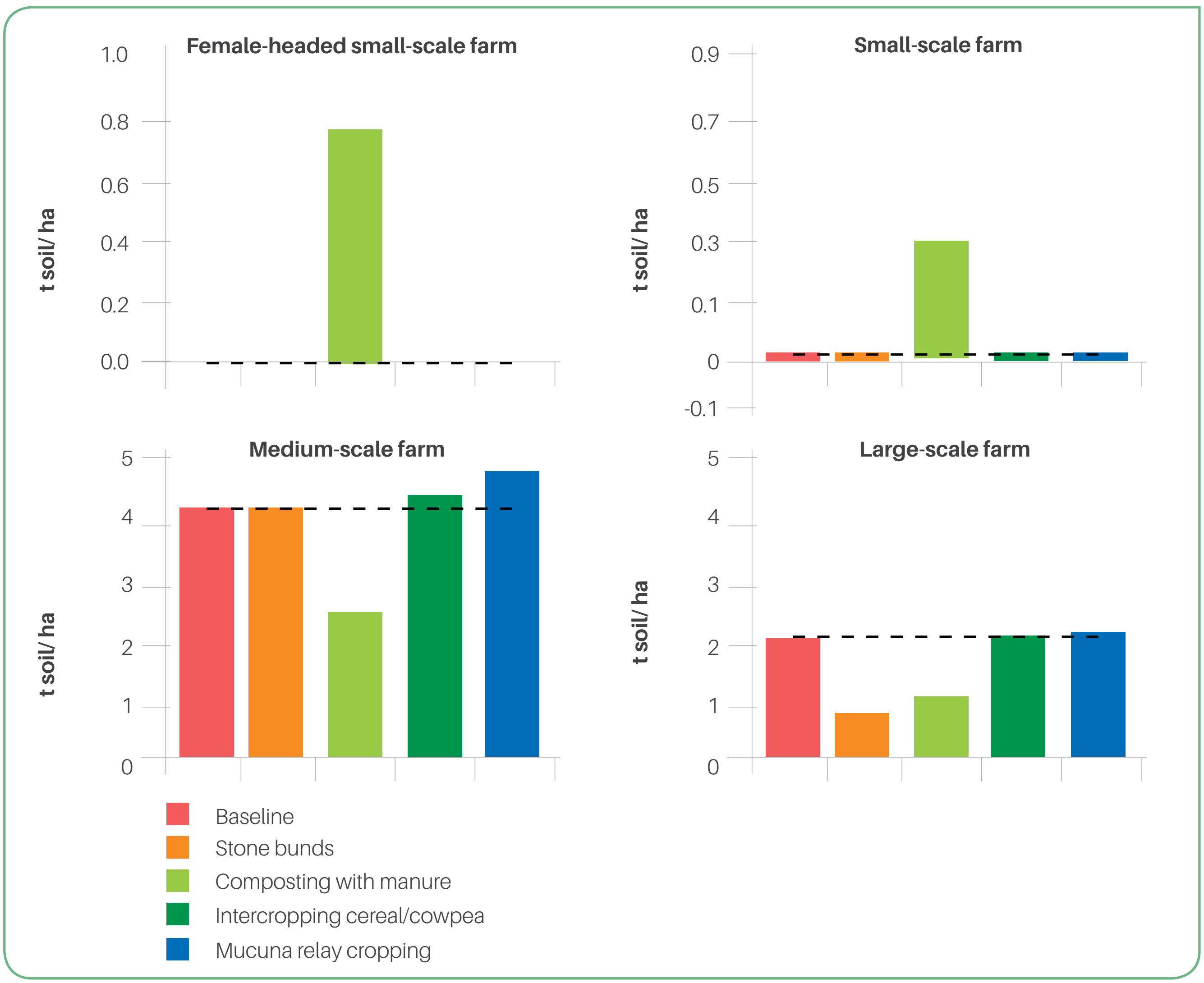


Figure 10. GHG emission intensity baselines and scenarios across farms (t CO_2e/ha).

5.4 Trade-offs

Truly triple-win climate-smart solutions, i.e. interventions that increase productivity, improve resilience and reduce GHG emissions, are rare. Instead, implementing soil conservation and rehabilitation measures often has a positive impact on just one or two of the CSA pillars but a negative effect on the remainder(s); i.e. trade-offs have to be made. Plotting changes in productivity against changes in N balance allows for a few insights (Figure 11). Firstly, composting with manure is the only clear win-win intervention, increasing productivity and N balance on most farms. The only exception is the medium-scale farm, where the notable productivity increase associated with compost application goes hand in hand with a small decrease in N balance. The N balance, however, remains positive on this farm too. Secondly, intercropping shows the biggest increases in productivity (except on the small-scale farm). This positive impact, however, needs to be traded off with decreases in N balance. Thirdly, relay cropping on the medium- and large-scale farms has a positive impact on the N balance with barely any trade-off observed in terms of productivity.

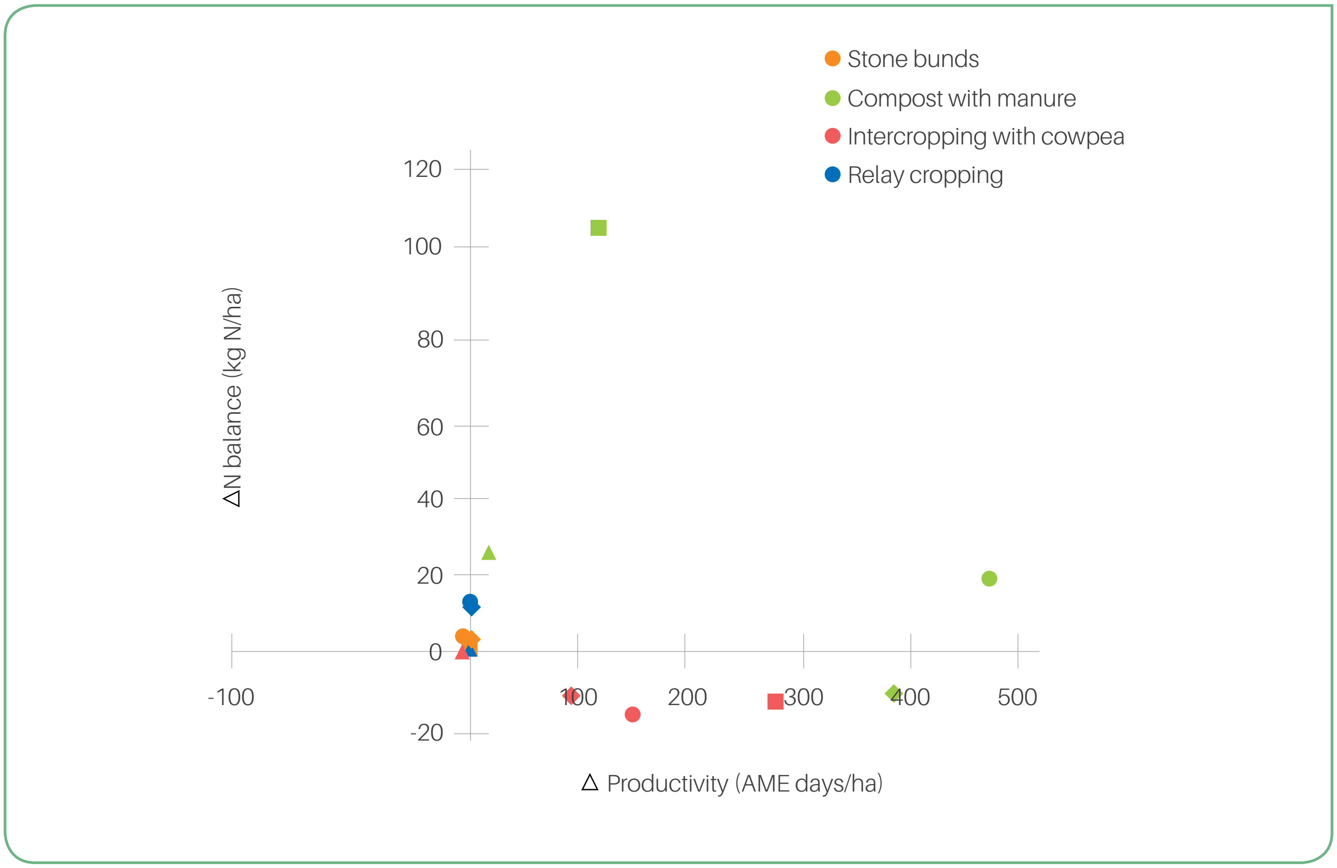


Figure 11. Trade-offs between changes in productivity (AME days/ha) and field N balance (kg N/ha) when moving from baseline to soil conserving technologies. Colours represent the scenario and shape the farm types (□=female-headed small-scale, △=small scale, ◇ =medium scale and ○= large scale).

Also within only one pillar, trade-offs can be observed (Figure 12). Comparing the impact of the interventions on soil erosion and N balance, shows that firstly, intercropping has a positive effect on soil erosion but shows a clear trade-off in terms of reducing the N balance on all farm types. Secondly, relay cropping represents a win-win solution, be it with small positive impacts in general and hardly any on the small farm. Thirdly, stone bunds show a positive impact on soil erosion with small but positive interaction with the N balance on the small female-headed and medium farm. On the small and large farms, on the other hand, the gains in terms of soil erosion come with a small trade-off in terms of N balance. Lastly, the loss in N balance caused by intercropping is compensated by small reductions in erosion.

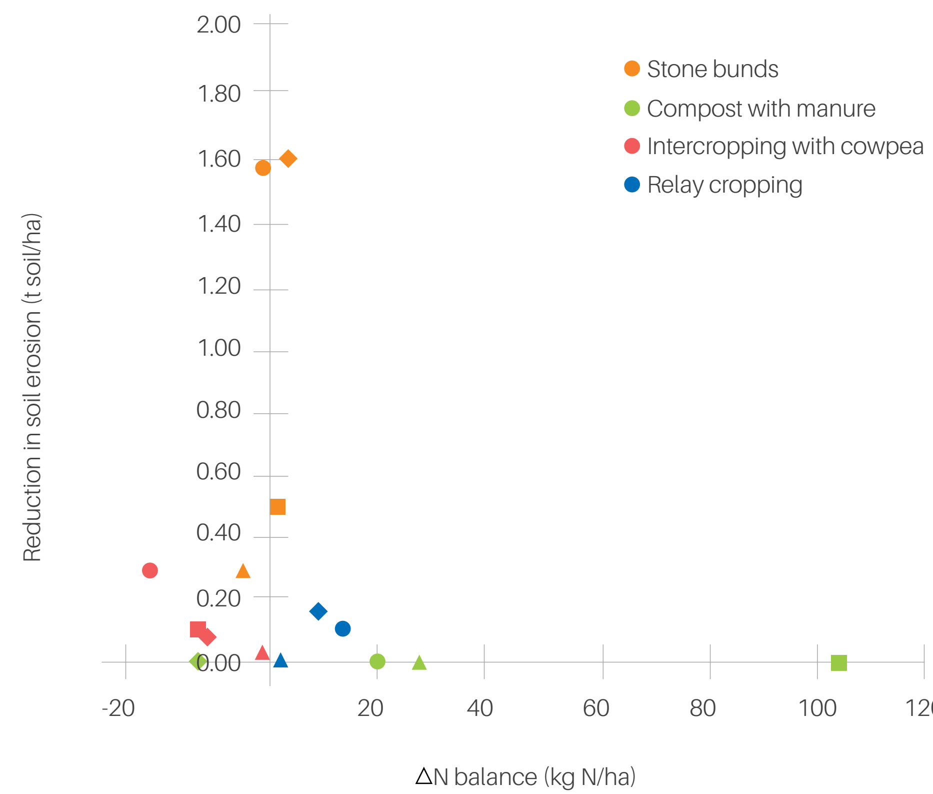


Figure 12. Trade-offs between changes in field N balance (kg N/ha) and Reduction in soil erosion (t/ha) comparing baseline and soil conservation scenarios. Colours represent the scenario and shape the farm types (☐=female-headed small-scale, △=small scale, ◇=medium scale and ○= large scale).

As for synergies and trade-offs between productivity and GHG emissions (Figure 13), the impact of the compost with manure intervention varies considerably between farm types. On medium- to large-scale farms, it represents a win-win solution. On the small farms, the increase in productivity comes with an increase in GHG emission intensity too. Finally, comparing soil erosion reduction with GHG emission intensity impacts (Figure 14), shows that a reduction in soil erosion is possible without big trade-offs in terms of GHG emission intensities, through e.g. stone bunds. Relay cropping also reduces soil erosion on the medium- and large-scale farms, but puts a trade-off, namely a higher GHG emission intensity.

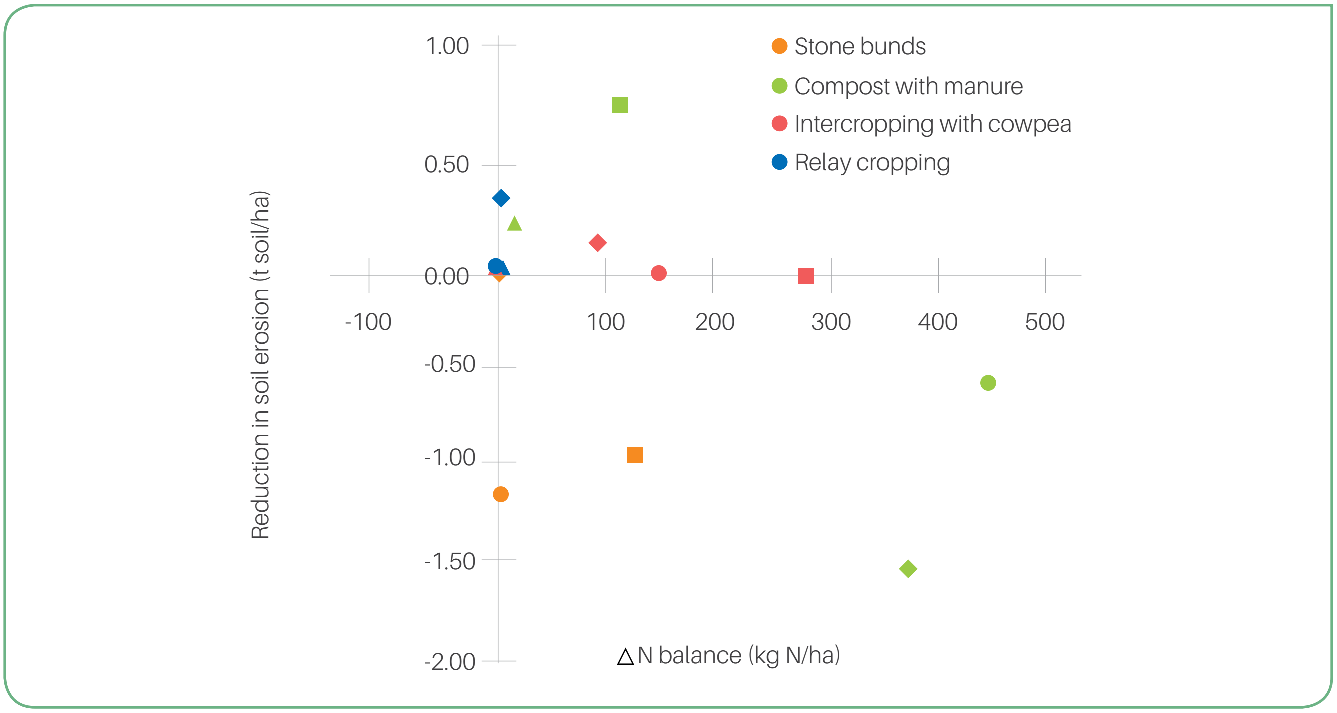


Figure 13. Trade-offs between changes in productivity (AME days/ha) and GHG emissions (t CO_2e/ha) comparing baseline and soil conservation scenarios. Colours represent the scenario and shape the farm types (□=female-headed small-scale, △=small scale, ◇=medium scale and ○= large scale).

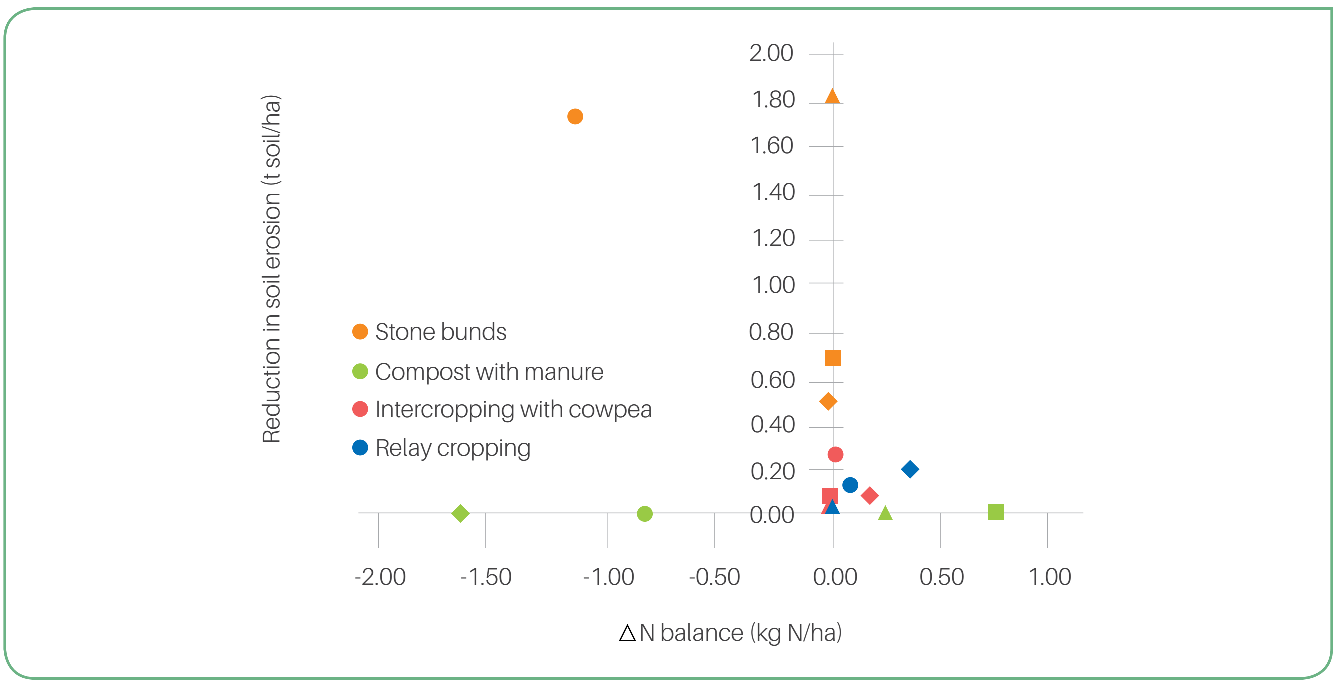


Figure 14. Trade-offs between changes GHG emissions (t CO_2e/ha) and Reduction in soil erosion (t/ha) comparing baseline and soil conservation scenarios. Colours represent the scenario and shape the farm types (□=female-headed small-scale, △=small scale, ◇=medium scale and ○= large scale).

6. Conclusions and recommendations

In this report a fairly simple set of four indicators was used for assessing the climate-smartness of farm types and soil protection and rehabilitation measures in Burkina Faso. This allowed for a truly rapid assessment that can feed into decision-making processes in the on-going GIZ Soil Program.

The choice of indicators has its limitations. The use of a calorie-based production of crops, milk and eggs as a productivity indicator disadvantages farms with higher importance of livestock production as compared to staple crops. The livestock farms are first of all disadvantaged by the exclusion of meat, secondly by the low calorie content of milk and eggs. The high protein content of livestock products renders them however very important for nutrition security, especially so for young children and pregnant women. This should be kept in mind when evaluating production. In other words: "It is not only about calories produced". Adding up calories produced from the various crops and livestock products and comparing business-as-usual with best-bets, is however a simple and easy-to-grasp way of indicating changes.

Focusing on soil fertility and erosion as the resilience indicator excludes a large number of important issues that contribute to farmers' resilience to climate change, such as income stability, access to skills, finances and information, crop/livestock diversity, etc. The list of indicators taken into account in this rapid assessment will therefore be expanded in the next stage of the project during the in-depth assessment. Indeed soil organic carbon could not be modelled in the rapid assessment. SOC has the potential to offset GHG emissions through carbon sequestration.

Despite the shortcomings of the indicators used, the rapid assessment clearly shows that there is a huge variation in the baseline climate-smartness across different farm types. In these case study farms, the small farms show a very low productivity, negative N balance, but also a very low GHG emission intensity. The higher input use in the medium- to large-scale farms increases their productivity and N balance, but comes with a trade-off in higher GHG emission intensities. Increasing the input use on the small farms through compost with manure increases their productivity as well as N balance without increasing soil erosion. And even as GHG emissions increase, their intensity would still remain very low. Increasing the productivity on the medium- and large-scale farms e.g. through compost or intercropping are expected to come with GHG emission intensity reductions but reductions in N balance, if these are sought to be implemented as a way of reducing the need to purchase and apply mineral N-fertilizer. The assessment thus shows that the impact of the interventions varies across the farm types. This points to the importance of targeting not only to bio-physical/agro-ecological environments but also taking into account the socio-economic context and associated farming practices.

Appendix I: Surveyed farm details

Table 1. Household size, land sizes and management per farm type. *Area managed refers to cultivated land, pasture, tree plots, fallow and unutilized land that is managed by the household. Area under cultivation refers only refers to land being cultivated by the household.*

Farm type	Household members (number)	Farm size (ha)	Area managed (ha)	Area cultivated (ha)
Female-headed small-scale farm	5	1.5	1.5	1.5
Small-scale farm	4	3.25	3.25	3.25
Medium-scale farm	19	7	7	7
Large-scale farm	18	24	24	20.5

Table 2. Crops yields per farm type. *Not applicable (NA) indicates that the respective crop is not grown on the farm. All yields are reported in fresh weight (FW).*

Farm type	Grain yields of cereal crops (kg FW/ha/year)			Yields of cash crops (kg FW/ha/year)		Yields of legume crops (kg FW/ha/year)		
	Maize	Sorghum	Rice	Cotton	Sesame	Cowpea	Groundnut	Soybean
Female-headed small-scale farm	NA	NA	NA	NA	NA	NA	260	220
Small-scale farm	400	NA	NA	NA	46	272	168	NA
Medium-scale farm	3500	1600	NA	1700	NA	1280	600	NA
Large-scale farm	3600	NA	2040	1162	NA	320	777	NA

Table 3. Fertilizer application rates (kg/ha).

Farm type	Maize		Cotton		Rice	
	NPK 14% (kg N/ha)	Urea (kg N/ha)	NPK 14% (kg N/ha)	Urea (kg N/ha)	NPK 14% (kg N/ha)	Urea (kg N/ha)
Female-headed small-scale farm	NA	NA	NA	NA	NA	NA
Small-scale farm	2.24	3.68	NA	NA	NA	NA
Medium-scale farm	28	23	21	23	NA	NA
Large-scale farm	35	23	21	23	14	23

Table 4. Livestock herd composition (no.) and total TLU.

Farm type	Local cattle (no.)	Improved cattle (no.)	Other cattle, male and heifers (no.)	Calves (no.)	Sheep (no.)	Goats (no.)	Pigs (no.)	Poultry (no.)	Total TLU (no.)
Female-headed small-scale farm	0	0	0	0	0	0	0	0	0
Small-scale farm	0	0	0	0	0	0	0	40	0.4
Medium-scale farm	8	0	13	4	20	0	0	100	70.9
Large-scale farm	6	0	11	0	7	0	9	25	52.45

Table 5. Crop residue management for the main crops (fraction removed from the fields 0-1). Cotton branches are burned directly in the field after being piled up.

Farm type	Maize	Sorghum	Rice	Cotton	Soybean	Cowpea	Groundnut	Sesame
Female-headed small-scale farm	NA	NA	NA	NA	NA	1	1	NA
Small-scale farm	1	NA	NA	NA	1	NA	1	1
Medium-scale farm	0.5	0.05	NA	1	NA	1	1	NA
Large-scale farm	1	1	1	0	NA	1	1	NA

Table 6. Whereabouts of ruminants (fraction of the day 0-1) and manure collection and use (%).

Farm type	Cattle				Sheep				Manure collection (%)		Manure collected used for fertilization (%)
	Stable	Yard	Pasture	Off-farm	Stable	Yard	Pasture	Off-farm	Stable	Yard	
Female-headed small-scale farm	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Small-scale farm	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Medium-scale farm	0	0.25	0.13	0.36	0	0.25	0.25	0.5	NA	75%	100%
Large-scale farm	0	0*	0.25	0.75	0.5	0.17	0.33	0	85%	75%	100%

* Draft bulls spent 0.5 in yard and 0.5 off-farm.

Table 7. Whereabouts of non-ruminants (fraction of the day 0-1).

Farm type	Chicken				Pigs			
	Stable	Yard	Pasture	Off-farm	Stable	Yard	Pasture	Off-farm
Female-headed small-scale farm	NA	NA	NA	NA	NA	NA	NA	NA
Small-scale farm	0	1	0	NA	NA	NA	NA	NA
Medium-scale farm	0	0	0.5	0.5	NA	NA	NA	NA
Large-scale farm	0.5	0.5	0	0	0.5	0.5	0	0

Appendix II: Scenario Assumptions

Table 8. Impact dimensions definitions (ID).

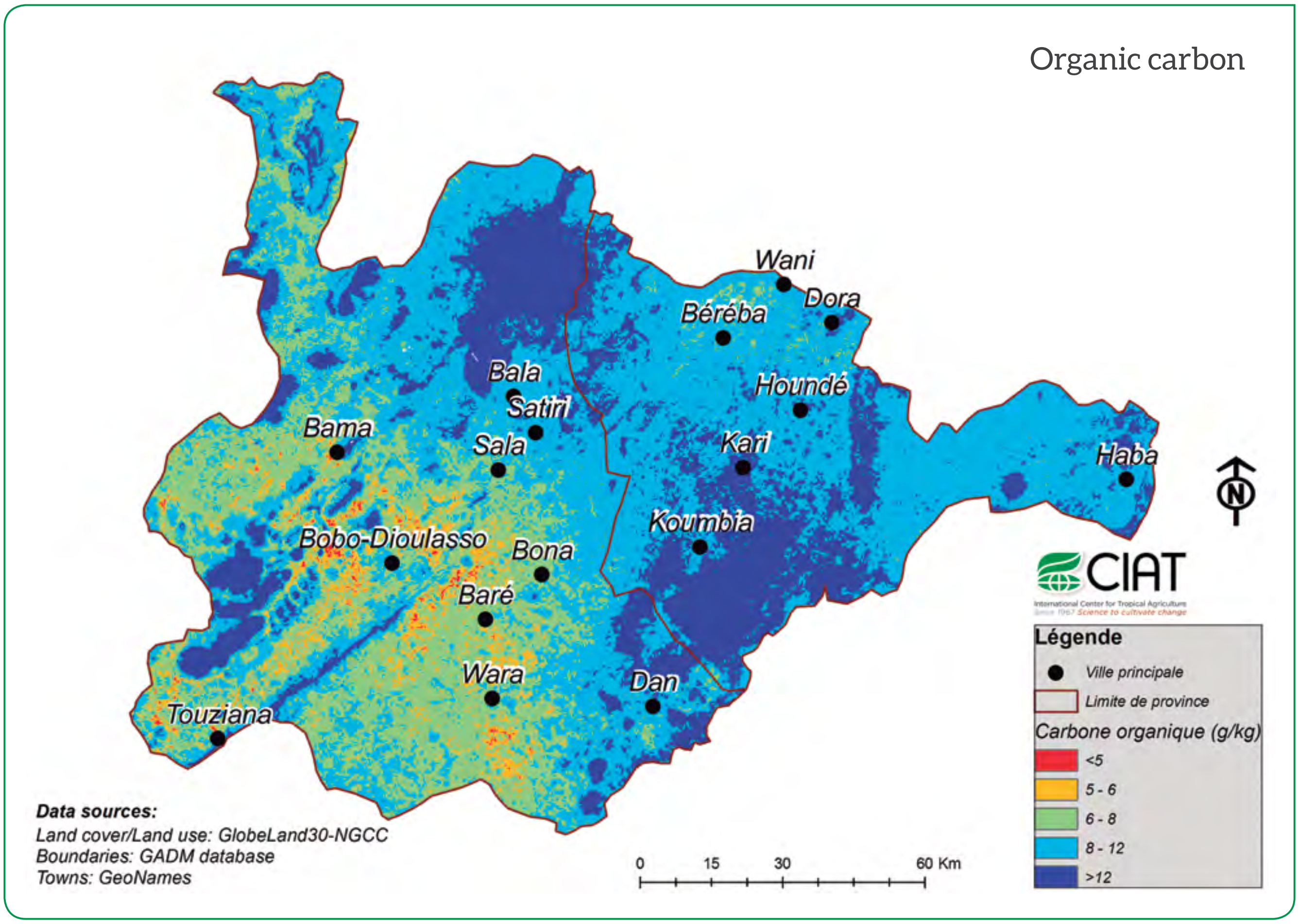
	Impact dimension
1	Land use change
2	Fertilizer application
3	Manure application
4	Crop yield
5	Milk production
6	Residue management
7	Soil erosion

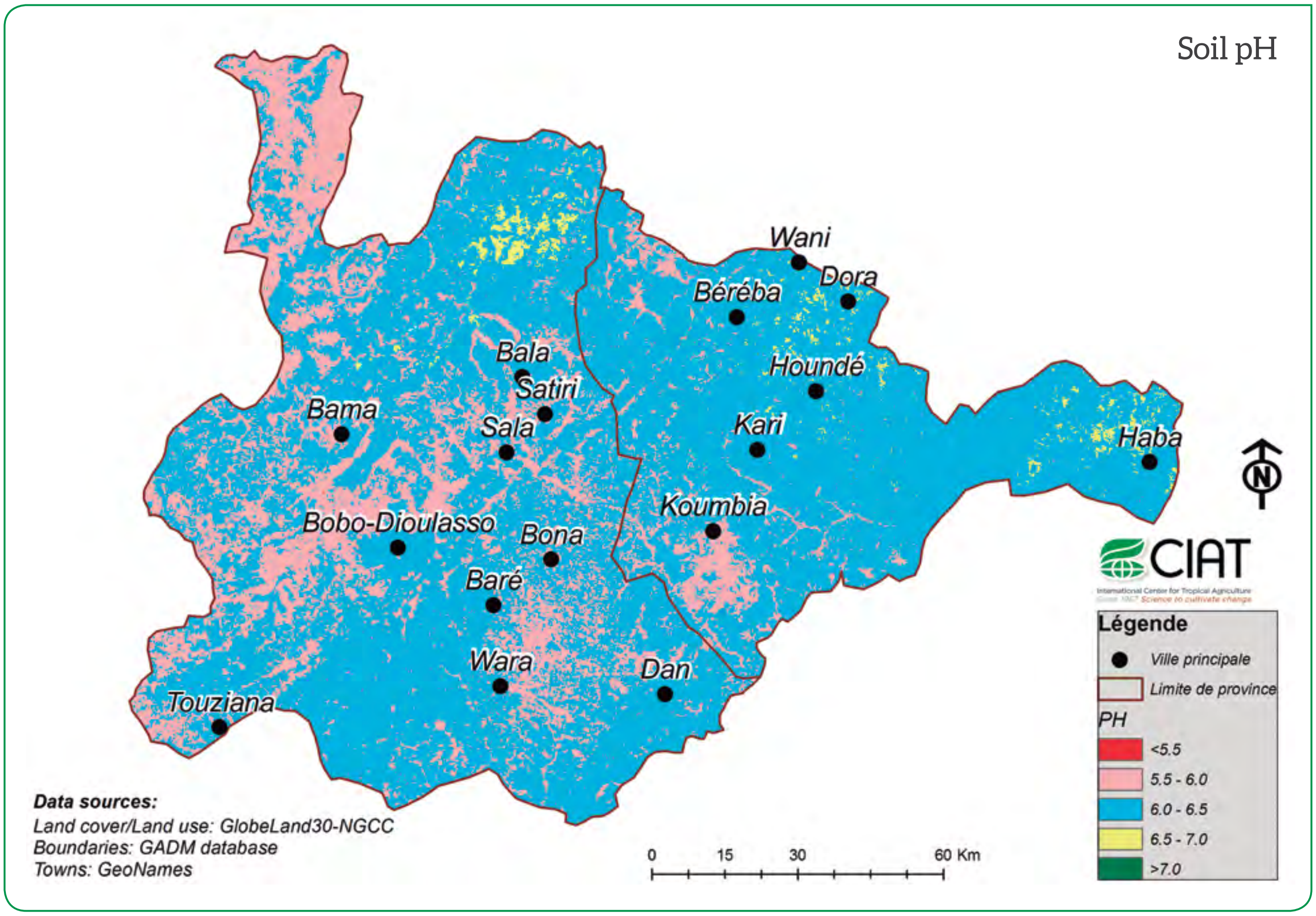
Table 9. Assumptions for all scenarios across farm types.

Farm	ID	Stone bunds	Composting with manure	Intercropping sorghum/or maize with cowpea	Relay cropping with mucuna
Female-headed small scale	1	Decrease all plot sizes by 10%	No change	Introduced sorghum to intercrop with currently grown cowpea (1 ha).	NA
Small scale	1	Decrease all plot sizes by 10%	No change	Intercrop with maize plot (0.25 ha)	Relay with maize (0.25 ha)
Medium scale	1	Decrease all plot sizes by 10%	No change	Intercrop with maize plot (3 ha)	Relay with maize (3 ha)
Large scale	1	Decrease all plot sizes by 10%	No change	Intercrop with maize plot (10 ha)	Relay with maize (10 ha)
Female-headed small scale	2	NA	NA	NA	NA
Small scale	2	No change	No reduction because using so little	No reduction because using so little	NA
Medium scale	2	No change	Reduced fertilizer application by 50%- except on cotton	Reduce NPK application by 30% (no reduction in top dressing)	Reduce N only in cotton assumed to be following maize/mucuna plot
Large scale	2	No change	Reduced fertilizer application by 50%- except on cotton	Reduce NPK application by 30% (no reduction in top dressing)	Reduce N only in cotton assumed to be following maize/mucuna plot
Female-headed small scale	3	NA	Imported Compost/Manure (3% N content) to meet the recommended 5 t DM/ha.	NA	NA
Small scale	3	No change-not applying	For 5 t DM/ha rate: need to import a total of 4.3 t DM (3% N content) to fertilize only 1 ha on this farm. Applied to the maize and sesame plots; 21kg N are provided by collecting and composting ALL crop residues (30% N loss in the composting process)	No change-not applying	No change-not applying
Medium scale	3	no change	Currently producing enough for 1 ha manure/compost for 1 ha of maize. So imported another 10t DM for the other 2 ha of maize	No change- applying to 1 ha maize	No change

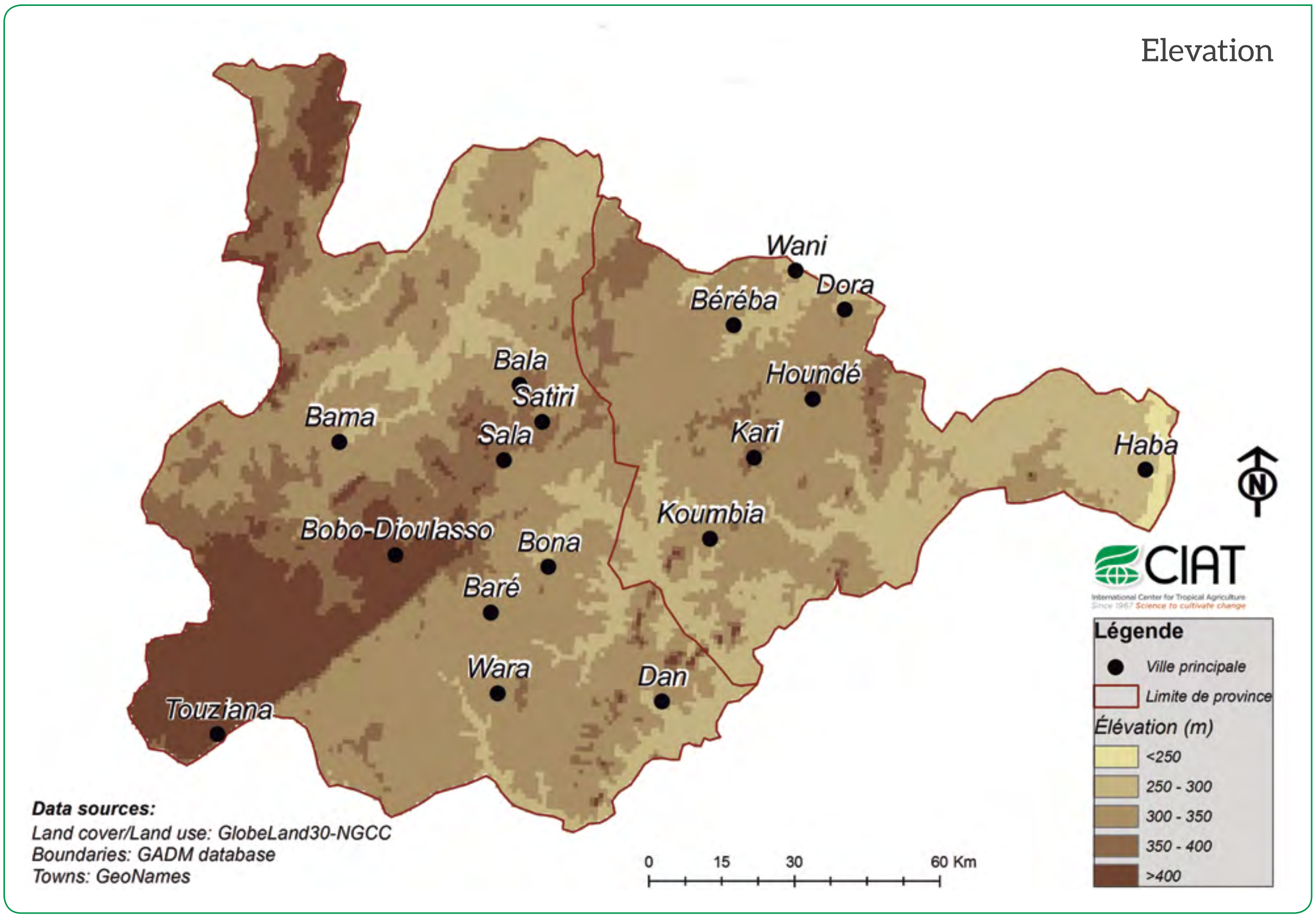
Farm	ID	Stone bunds	Composting with manure	Intercropping sorghum/or maize with cowpea	Relay cropping with mucuna
Large scale	3	No change	Imported compost/manure for 10 ha of maize at 5 t DM/ha	No change- applied all to the 10 ha maize	No change
Female-headed small scale	4	Loss in crop area compensated by increase in yield-> no change from the baseline.	Increased yields by 20%	Reduced cowpea yields by 70% and sorghum by 20%	NA
Small scale	4	Loss in crop area compensated by increase in yield-> no change from the baseline.	Increase yields maize and sesame yields by 20%	Reduced cowpea yields by 70% (for that plot) and maize by 20%	Improve maize an sesame yields by 10 %
Medium scale	4	Loss in crop area compensated by increase in yield-> no change from the baseline.	Increase maize yields by 20%	Reduced cowpea yields by 70% (for that plot) and maize by 20%	Improve cotton yields by 10%- no calories
Large scale	4	Loss in crop area compensated by increase in yield-> no change from the baseline.	Increase maize yields by 20% for ONLY 1 ha	Reduced cowpea yields by 70% (for that plot) and maize by 20%	Improve cotton yields by 10%- no calories
Female-headed small scale	5	NA	NA	NA	NA
Small scale	5	NA	No change - only poultry	No change	NA
Medium scale	5	NA	No residues fed to livestock	No change- more cowpea residues to feed, 10% increase in livestock production	Livestock graze on mucuna -> 10% overall increase in productivity
Large scale	5	NA	No residues fed to livestock	No change- more cowpea residues to feed, 10% increase in livestock production	Livestock graze on mucuna -> 10% overall increase in productivity
Female-headed small scale	6	No change	No change- currently all removed	No change	NA
Small scale	6	No change	No change- currently all removed	No change	Leave 100% of mucuna residue on the field
Medium scale	6	No change	All residues removed +no burning of cotton residues	No change- all cowpea residues are removed	Leave 100% of mucuna residue on the field to be grazed
Large scale	6	No change	All residues removed +no burning of cotton residues	No change	Leave 100% of mucuna residue on the field to be grazed
Female-headed small scale	7	Decrease P factor from 0.8 to 0.27 (Nill et al., 1996)	No change	Reduce P factor from 0.8 to 0.6 in intercropped field	NA
Small scale	7	Decrease P factor from 0.8 to 0.27 (Nill et al., 1996)	No change	Reduce P factor from 0.8 to 0.6 in intercropped field	Reduce P factor from 0.8 to 0.7 in the maize field
Medium scale	7	Decrease P factor from 0.8 to 0.27 (Nill et al., 1996)	No change	Reduce P factor from 0.8 to 0.6 in intercropped field	Reduce P factor from 0.8 to 0.7 in the maize field
Large scale	7	Decrease P factor from 0.8 to 0.27 (Nill et al., 1996)	No change	Reduce P factor from 0.8 to 0.6 in intercropped field	Reduce P factor from 0.8 to 0.7 in the maize field

Appendix III: Reference maps of study sites

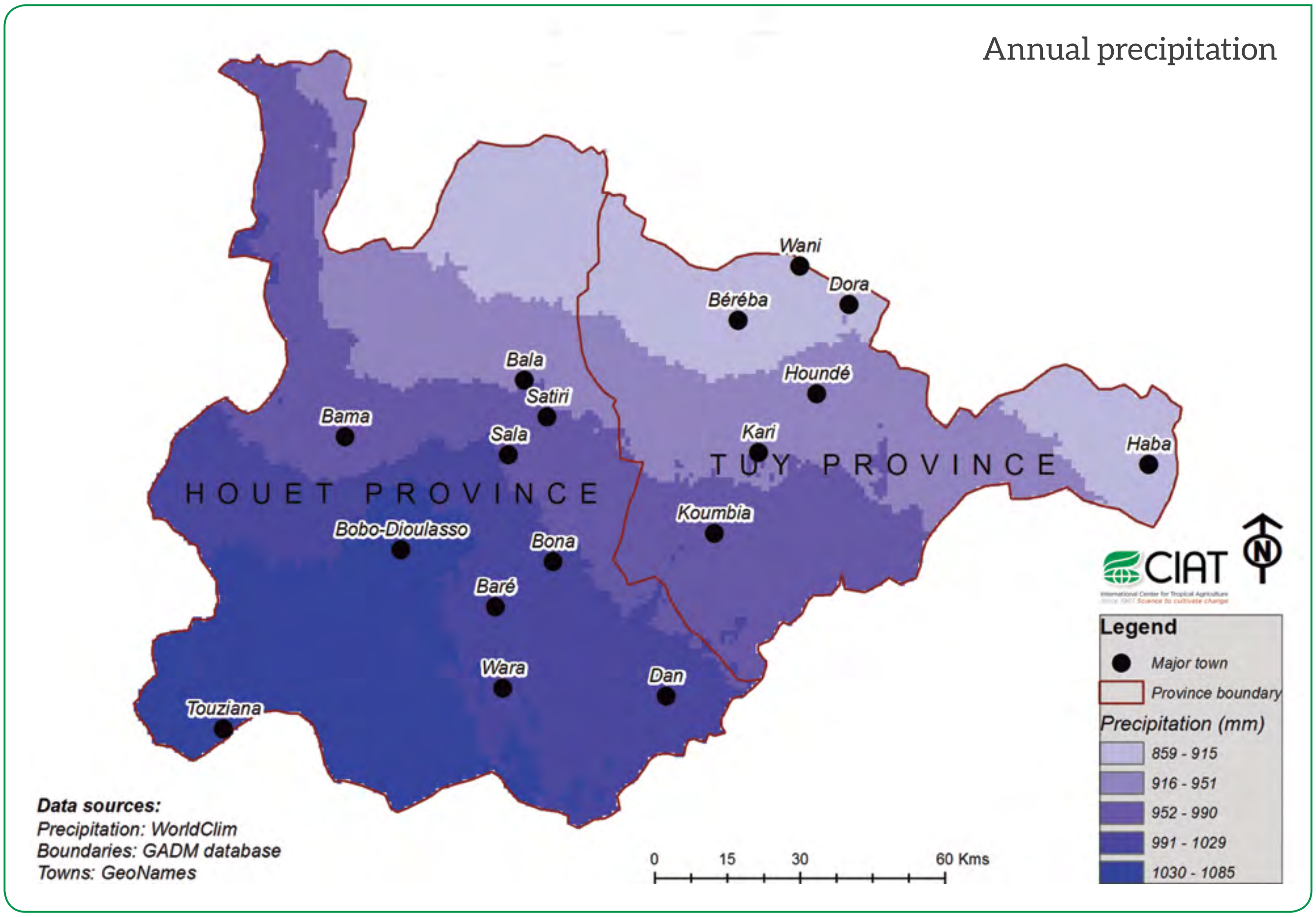


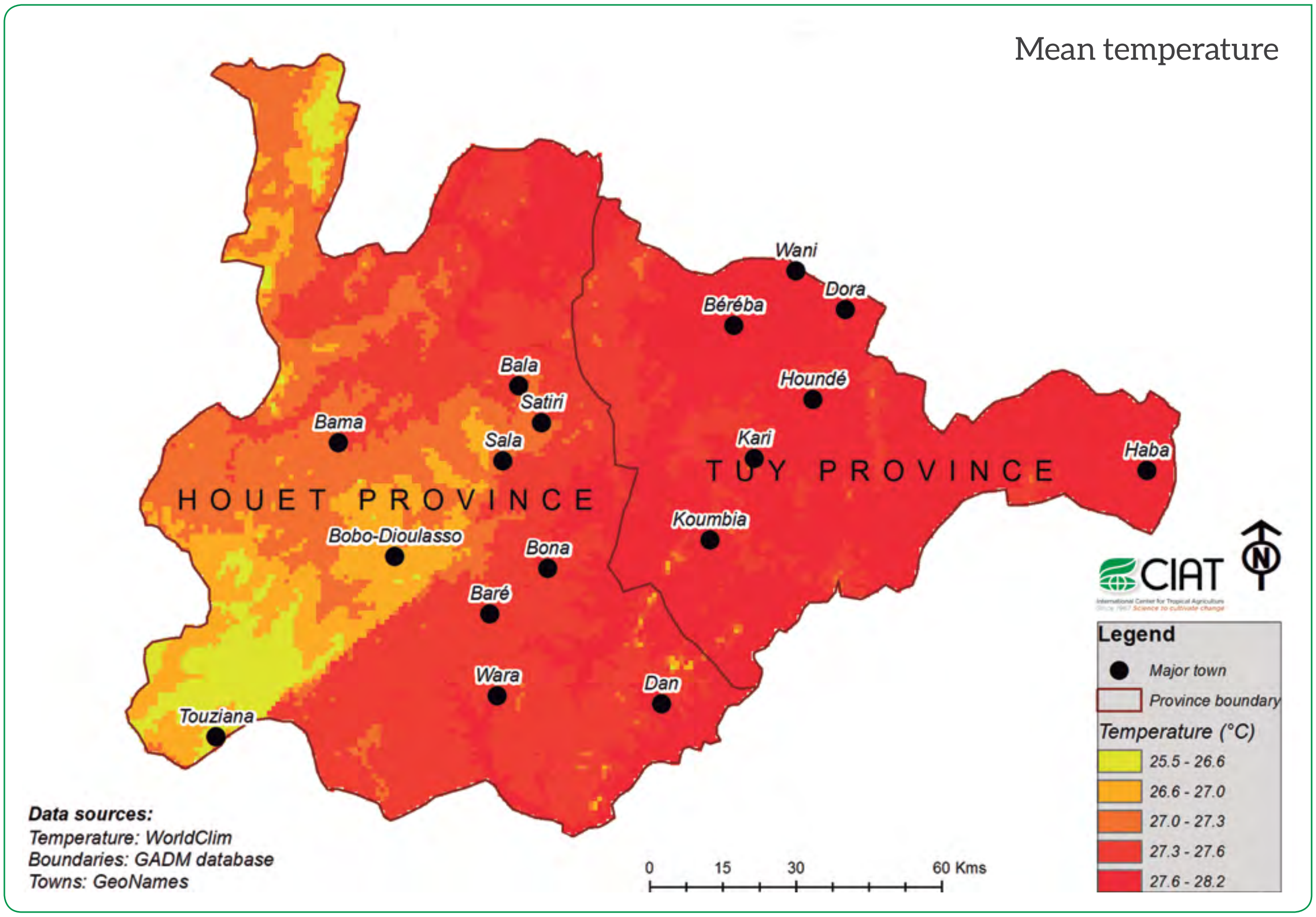


Soil pH
Wani
Dora
Béréba
Bala
Houndé
Satiri
Bama
Sala
Kari
Haba
Koumbia
Bobo-Dioulasso
Bona
Baré
Wara
Dan
Touziana
Data sources:
Land cover/Land use: GlobeLand30-NGCC
Boundaries: GADM database
Towns: GeoNames
0
15
30
60 Km
N
CIAT
Légende
Ville principale
Limite de province
PH
<5.5
5.5 - 6.0
6.0 - 6.5
6.5 - 7.0
>7.0



Elevation
Wani
Dora
Béréba
Bala
Satiri
Houndé
Bama
Sala
Kari
Haba
Koumbia
Bobo-Dioulasso
Bona
Baré
Wara
Dan
Touziana
CIAT
Légende
Ville principale
Limite de province
Élévation (m)
<250
250 - 300
300 - 350
350 - 400
>400
Data sources:
Land cover/Land use: GlobeLand30-NGCC
Boundaries: GADM database
Towns: GeoNames
0 15 30 60 Km
N


Annual precipitation
Wani
Dora
Béréba
Bala
Houndé
Satiri
Bama
Sala
Kari
TUY PROVINCE
Haba
HOUET PROVINCE
Bobo-Dioulasso
Bona
Koumbia
Baré
CIAT
N
Legend
Major town
Province boundary
Precipitation (mm)
859 - 915
916 - 951
952 - 990
991 - 1029
1030 - 1085
Wara
Dan
Touziana
Data sources:
Precipitation: WorldClim
Boundaries: GADM database
Towns: GeoNames
0
15
30
60 Kms


Mean temperature
HOUET PROVINCE
TUY PROVINCE
Wani
Dora
Béréba
Houndé
Bala
Satiri
Bama
Sala
Kari
Haba
Koumbia
Bobo-Dioulasso
Bona
Baré
Wara
Dan
Touziana
CIAT
Legend
Major town
Province boundary
Temperature (°C)
25.5 - 26.6
26.6 - 27.0
27.0 - 27.3
27.3 - 27.6
27.6 - 28.2
0 15 30 60 Kms
Data sources:
Temperature: WorldClim
Boundaries: GADM database
Towns: GeoNames

References

AGRA (Alliance for a Green Revolution in Africa). 2014. Micro Reforms for African Agribusiness MIRA: An Assessment of Agricultural Policy and Regulatory Constraints to Agribusiness Investment in Burkina Faso, Ethiopia, Ghana, Nigeria and Tanzania. AGRA, Nairobi.

Amdihun A; Gebremariam E; Rebelo L-M; Zeleke G. 2014. Suitability and scenario modeling to support soil and water conservation interventions in the Blue Nile Basin, Ethiopia. Environmental Systems Research, 3(1):23. Doi:10.1186/s40068-014-0023-9.

Burkina Faso. 2011. Programme National du Secteur Rural (PNSR), Ouagadougou.

Burkina Faso. 2013. Politique National de Développement Durable au Burkina Faso (PNDD), Ouagadougou.

Campbell BM; Thornton P; Zougmoré R; van Asten P; Lipper L. 2014. Sustainable intensification: What is its role in climate smart agriculture? Current Opinion in Environmental Sustainability, 8:39–43. Doi:10.1016/j.cosust.2014.07.002.

Grant W. 2005. Agricultural policy. Development in British Public Policy, pp. 7-23.

IPCC (Intergovernmental Panel on Climate Change). 2006. IPCC Guidelines for National Greenhouse Gas Inventories, Prepared by the National Greenhouse Gas Inventories Programme, Eggleston HS; Buendia L; Miwa K; Ngara T; Tanabe K. (eds). Published: IGES, Japan.

Kalčić Š; Birnholz C. 2016. La climato-intelligence des mesures de protection et de réhabilitation des sols dans la région des Hauts-Bassins au Burkina Faso. Rapport d'Atelier de Travail. 17 March 2016, Bobo Dioulasso, Burkina Faso.

Klapwijk C; van Wijk M; Rosenstock T; van Asten P; Thornton P; Giller K. 2014. Analysis of trade-offs in agricultural systems: current status and way forward. Current Opinion in Environmental Sustainability, 6:110–115.

Lipper L; Thornton P; Campbell BM; Baedeker T; Braimoh A; Bwalya M; Torquebiau EF. 2014. Climate-smart agriculture for food security. Nature Climate Change, 4:1068-1072. Doi:10.1038/nclimate2437.

Nill D; Schwertmann U; Sabel-Koschell U; Bernhard M; Breuer J. 1996. Soil Erosion by Water in Africa - Principles, Prediction and Protection. 291 p. Retrieved 16 May 2016, from http://bit.ly/2hxZAzq

Renard KG; Foster GR; Weesies GA; Porter JP. 1991. RUSLE: Revised Universal Soil Loss Equation. J. Soil Water Conserv. 46(1):30-33. www.jswconline.org/content/46/1/30.extract

Smith P; Martino D; Cai Z. et al. 2007. Agriculture. In: Chapter 8 of Climate change 2007; Mitigation. Contribution of Working Group III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Metz B; Davidson OR; Bosch PR; Dave aR; Meyer LA. (eds). Cambridge University Press, Cambridge, UK, and New York, USA. pp. 497-540.

Sigunga DW. 2011. Land and Soil Resources and their Management for Sustainable Agricultural Production in Kenya: Current Position and Future Challenges. Egerton Journal of Science and Technology (ISSN 2073-8277), pp. 66.

Van den Bosch H; De Jager A; Vlaming J. 1998. Monitoring nutrient flows and economic performance in African farming systems (NUTMON) II Tool development. Agriculture, Ecosystems and Environment 71:49–62. Doi:10.1016/S0167-8809(98)00131-5.

Headquarters and Regional Office for Latin America and the Caribbean

Km 17 Recta Cali–Palmira CP 763537
Apartado Aéreo 6713
Cali, Colombia
Phone: +57 2 4450000
Fax: +57 2 4450073
General e-mail: ciat@cgiar.org

CONTACT
Carolina Navarrete, Coordinator
c.navarrete@cgiar.org

Regional Office for Africa

c/o ICIPE
Duduville Campus,
Off Kasarani Road
P.O. Box 823-00621
Nairobi, Kenya
Phone: +254 20 8632800 /
+254 719 052800 / 721 574967
Fax: +254 20 8632001

CONTACT
Adebisi Araba, Regional Director
a.araba@cgiar.org

Regional Office for Asia

c/o Agricultural Genetics Institute (Vien Di Truyen Nong Nghiep), Vietnam Academy of Agricultural Sciences (VAAS), Pham Van Dong Street, Tu Liem (opposite the Ministry of Security – Doi dien voi Bo Cong An)
Hanoi, Vietnam
Phone: +844 37576969

CONTACT
Dindo Campilan, Regional Director
d.campilan@cgiar.org

A CGIAR Research Center

www.ciat.cgiar.org

www.cgiar.org