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Food self-sufficiency and land gap analysis of smallholders in humid and semi-arid sub Saharan Africa

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Preface

The CGIAR Research Program on Integrated Systems for the Humid Tropics seeks to transform the lives of the rural poor in the humid lowlands, moist savannahs and tropical highlands in three major Impact Zones of sub-Saharan Africa and tropical America and Asia, presently containing a population of 2.9 billion people, mostly poor smallholder farmers. Humidtropics research is guided by a Global Hypothesis 'A range of livelihood strategies exists within the humid tropics where poverty reduction, balanced household nutrition, system productivity and natural resource integrity are most effectively achieved and contribute best to human welfare'. A dynamic program structure is built around three complementary Strategic Research Themes; Systems Analysis and Synthesis, Integrated Systems Improvement, and Scaling and Institutional Innovations. Change in rainfed, smallholder farming systems in the tropics is gradual, adaptive, and stepwise; responding primarily to changes in market conditions, farmer-available resources, and increasingly, to changes of climate. Humidtropics seeks first to improve understanding of these processes in terms of alternative intensification pathways and critical points of intervention and then to design new interventions that direct intensification toward desired outcomes. The assessment and analysis of the existing systems is an essential step in the identification of these critical intervention options, and here Humidtropics wants to make use of existing datasets that characterize livelihood systems. The N2AFRICA project (funded by The Bill & Melinda Gates Foundation) is a large scale, science-based 'research-in-development' project focused on putting nitrogen fixation to work for smallholder farmers growing legume crops in Africa. Within this project, led by Wageningen University, a large farming system and livelihood characterization exercise has been executed across eight different countries in sub Saharan Africa. These characterization data form an excellent source of information on livelihood strategies, and a basis to test different approaches for systems analysis to try to identify where certain interventions have the potential to improve the livelihoods of smallholder farmers. This report describes the outputs generated by such an analysis in a collaboration between researchers of Wageningen University and Research Centre (WUR), the International Institute of Tropical Agriculture (IITA) and the International Livestock Research Institute (ILRI). We thank Greta van den Brand (WUR) for discussions on the data.

Executive summary

Market-based and value chain approaches dominate in the debate on the role of smallholder agriculture in reducing rural poverty and improving global food security. The underlying assumption of these approaches is that through the connection of smallholders with regional and global markets incomes and livelihoods will improve. The classification of the 'Rural Worlds' has been coined to position smallholders within the continuum of rural poverty and market integration. Smallholders of Rural World 1, which are well-connected to international and national markets are one side of the spectrum but are scarce in sub Saharan Africa. Rural World 2 comprises a large proportion of smallholders with little or infrequent market contacts. At the other end of the spectrum is Rural World 3 with smallholders who are net consumers. A better understanding of what proportion of smallholders are part of which Rural World provides important background to identify pathways for market-based development and for better targeting of R&D efforts. In addition, characterisation of smallholders in the different Rural Worlds helps to identify which rural households are likely to participate in value chains and to design alternative pathways for alleviating hunger and poverty among the poorest households.

In this study we analyse a large data set from the N2Africa project (www.N2Africa.org) with baseline information of more than 3000 farm households from eight countries in humid and semi-arid SSA, i.e. the DRC, Ghana, Kenya, Malawi, Mozambique, Nigeria, Rwanda and Zimbabwe. Within these countries households are clustered into three to five action sites per country, totalling 29 action sites. We combine information on household land assets with local production data to estimate land requirements for achieving food self-sufficiency of individual farm households. Based on the land requirements a 'land gap' is quantified for those households that are food insecure, or a 'land surplus' for those households that are able to produce food beyond own household needs and thus may be able to produce for the market. This provides information on the proportion of small-scale farmers that could participate in market-based development and the proportion of farmers for which other development efforts and pathways are needed. In addition, by combining the 'land surplus' information with cost-benefit analyses of cash crops the effect of market-based production on household income and reducing household poverty is quantified. We use maize as indicator crop for achieving food self-sufficiency and soybean as indicator crop for cash crop production at surplus land. Because technological development is a major driver of change, we enrich the analyses with three scenarios to gain insight in the potential impact of production intensification on closing the land gap and increasing household income, (i) Baseline Scenario based on current yield levels, (ii) a doubling of actual maize yields and fertilisation of soybean with P fertilizer (Scenario 2) and (iii) 80% of water-limited maize yields combined with attainable soybean yields using a combination of P fertilizers and inoculants (Scenario 3).

In the Baseline Scenario, less than 50% of the households achieved food self-sufficiency in the action sites of Rwanda, DRC and one action site in Kenya and in Zimbabwe. Overall gross returns from maize and soybean production were small with 20% of all farm households reaching the poverty benchmark of 1.25 USD cap^{-1} day^{-1}. In none of the countries or action sites did 50% of the households reach the poverty benchmark.

With a doubling of maize yields and 20 kg P ha^{-1} resulting in larger soybean yields (Scenario 2), food self-sufficiency for most households is within reach, except for the action sites in Rwanda and one site in the DRC where approximately 50% of the households remained food deficient. In this scenario, in three of the 29 action sites more than 50% of the households were able to achieve an income of more than 1.25 USD cap^{-1} day^{-1}.

In the most intensive Scenario 3 food self-sufficiency of the action sites of Rwanda and one site in the DRC improved but still 10-20% of the households remained food deficient. In this scenario, 12 out of the 29 action sites at least 50% of the households reach the poverty benchmark, in the other 17 action sites (often much) less than 50% of the households were able to earn 1.25 USD cap^{-1} day^{-1}. Especially, households in Zimbabwe, Nigeria, Ghana and two action sites in the DRC are better off, while households in Malawi and Rwanda are worst off. Overall 48% of all farm households in our data set achieved incomes of 1.25 USD cap^{-1} day^{-1} (or more) from maize and soybean production in the scenario with the highest production intensity.

Although this is a coarse analysis, the scenarios indicate the potential and the boundaries within which agricultural intensification can assist rural households in achieving food self-sufficiency on the one hand, and the potential benefits of market-based developments and associated impact on reducing rural poverty of smallholders on the other hand. Although yields used in the intensive scenarios are feasible, they are much greater than those achieved with farmers' current practices and would require substantial changes in management. While such yields allow to close the land gap of most households and free land for commercial production, impacts on reducing poverty as measured by the number of households earning more than 1.25 USD cap^{-1} day^{1} remain moderate.

The analysis of a large set of individual farm household data from a range of sites across humid and semi-arid sub-Saharan Africa contributes to the discussion on whether farms can step up to more remunerative Rural Worlds. Although the results show a diverse palette across SSA, among action sites within the same country and among households within the same action site, the overall picture is that intensification and diversification towards cash crops will not lift a great number of households out of poverty. Compared with the baseline situation, agricultural *intensification has the potential to improve food self-sufficiency for the majority of food deficient households but* allows only an additional 28% of our analysed household population to enter a Rural World where earnings from agriculture are more than 1.25 USD cap^{-1} day^{1}. Other options need to be explored to alleviate poverty for the remainder of the rural population that will not be able to benefit from market-based development of rain-fed cropping.

1. Introduction

Many governments, donors and companies have embraced the paradigm of 'market-based' development which attempts to link small-scale producers to regional and global formal markets (Seville *et al.*, 2001; Vorley *et al.*, 2012). The underlying assumption of these approaches is that market-integration of smallholders improves the incomes of the rural poor and contributes to securing global food supplies. Farm sizes across sub Saharan Africa (SSA) have gradually declined over the past 50 years and this raises the question whether most farms are not 'too small' to generate a meaningful production surplus to participate in regional and global markets (Jayne & Muyanga, 2013). Which and how many small-scale producers can participate in a market-based development? What are the potential benefits for those small-scale producers participating in value chains? And what is the role of technology to facilitate broad-based and inclusive market-based development?

Vorley *et al.* (2002) classified rural citizens into three 'Rural Worlds', which is useful to identify agricultural producers with different opportunities to become involved in market-based developments. Rural World 1 is composed of large scale farmers already embedded in national and international markets. Very few farmers in SSA, outside South Africa, meet the classification of Rural World 1. Rural World 2 consists mainly of family farms that are not (yet) internationally competitive but occasionally sell into markets, and Rural World 3 comprises subsistence households which struggle to survive through a combination of off-farm employment, (temporary) migration and agriculture. A better understanding of what proportion of smallholder farmers are part of Rural Worlds 2 and 3 provides an important background to identify pathways for market-based development and for targeting R&D efforts. In addition, characterisation of smallholders in the different Rural Worlds helps to identify which rural households are likely to participate in such development and to design alternative pathways for alleviating hunger and poverty among the poorest households. This approach to recognise the diversity of rural households thus contributes to Dorward's proposed dialogue for development as 'stepping up', 'stepping out' or 'hanging in' (Dorward, 2009).

Average farm sizes are decreasing across SSA because of population growth and land scarcity in many parts of SSA (Masters *et al.*, 2013; Harris & Orr, 2014). The land endowments of farm households in relation to food self-sufficiency needs and market-based production are relevant indicators to distinguish between the different Rural Worlds. If farm households are unable to produce sufficient food to satisfy own family needs they are much less likely to make the step to a more remunerative Rural World than farm households that are able to produce beyond family needs. For latter farm households the potential contribution of cash/market crops to their income and reducing poverty is relevant.

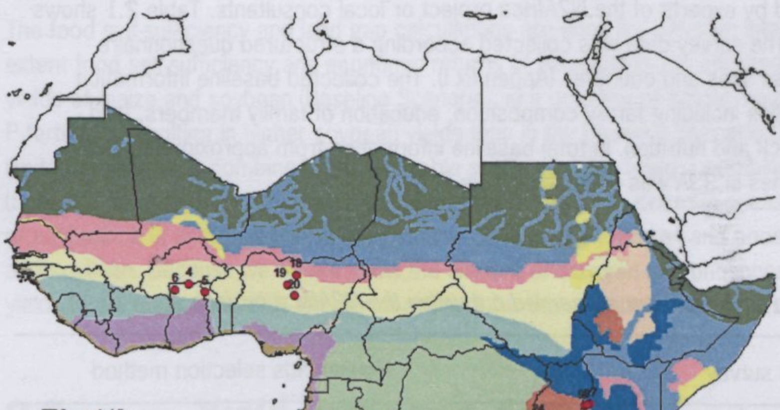
In this study we analyse a large survey data set from the N2Africa project (www.N2Africa.org) with baseline information of small-scale farm households from eight countries in SSA. We combine information on household land assets with local production data to estimate land requirements for achieving food self-sufficiency of these farm households. Based on these land requirements a 'land gap' is quantified for those households that cannot produce sufficient food to feed own household members, or a 'land surplus' for those households that are able to produce beyond own household food needs and thus may be able to produce for the market. This provides information on the proportion of small-scale producers that could participate in market-based development and the proportion of producers for which other development efforts and pathways are needed. In addition, by combining the 'land surplus 'information with cost-benefit analyses of cash crops the effect of market-based production on household income and reducing household poverty is quantified. Because technological development is a major driver of change, we enrich the analyses with different agricultural intensification scenarios to gain insight in the potential impact of production intensification (higher crop yields) on closing the land gap, increasing household income and reducing household poverty.

Commonly, methodologies aimed at analysing farm household systems use farm typologies to cluster farm households with similar characteristics (e.g. Rufino *et al.*, 2008; Tittonell *et al.*, 2010). Generally, farm typologies describe and cluster farm households based on resource endowments (land, labour, capital), production goals and aspirations, and production structure (type of crops, animals) (Norman *et al.*, 1995). Typologies are helpful for scaling up results and to design interventions and assess broader social and environmental impacts of farm activities. However, each farm household is unique, and by using a typology much of the diversity of farm households within and across clusters of farm households is lost. Further, consideration of future trajectories or appropriate technologies for different farm types needs to be linked to an understanding of the frequency with which the different farm types occur and to the availability of resources such as land and labour. Therefore, in this study we analyse food self-sufficiency and land requirements of more than 3000 individual farm households across SSA to capture their full diversity in resource endowments, food requirements and options to enter more remunerative Rural Worlds.

2. Material and Methods

2.1 General approach

We used baseline data of farm household surveys from the N2Africa project (www.N2Africa.org), which has the objectives to increase grain legume yields, biological nitrogen fixation, and household income in different action sites of eight countries in SSA, i.e. Democratic Republic of the Congo (DRC), Ghana, Kenya, Malawi, Mozambique, Nigeria, Rwanda and Zimbabwe. Figure 2.1 shows the different action sites in the farming systems map of Dixon *et al.* (2001). The action sites were spatially clustered within countries but differed in agro-ecological potential and market access (Table 2.1). The action sites were located within rainfed farming systems and selected on the basis of having relatively high agricultural potential and a high population density relative to other areas in these countries and other areas in SSA (Franke *et al.*, 2011). These characteristics were expected to provide greatest potential for sustainable intensification of agriculture using grain legumes.



	Country	Action site
1	DRC	Kalehe
2	DRC	Kabare
3	DRC	Walungu
4	Ghana	Northern region
5	Ghana	Upper East region
6	Ghana	Upper West region
7	Kenya	Wamalumu
8	Kenya	South Gem
9	Kenya	Bondo
10	Kenya	Kanyamkago
11	Malawi	Lilongwe
12	Malawi	Dowa
13	Malawi	Salima
14	Malawi	Ntcheu
15	Mozambique	Mandimba
16	Mozambique	Gurue
17	Mozambique	Sussundenga
18	Nigeria	Kano state
19	Nigeria	Northern Kaduna
20	Nigeria	Southern Kaduna
21	Rwanda	Musambira
22	Rwanda	Musenyi
23	Rwanda	Rukara
24	Rwanda	Burera
25	Rwanda	Gakenke
26	Zimbabwe	Guruve
27	Zimbabwe	Makoni
28	Zimbabwe	Mhondoro
29	Zimbabwe	Mudzi

Figure 2.1 *The action sites of the N2Africa project in eight countries of sub Saharan Africa where baseline information of farm households has been collected. The action sites are plotted against the background of the farming systems map of Dixon et al. (2001).*

The household data were used to identify opportunities for achieving food self-sufficiency and for producing cash crops in relation to the available land holding and the household food needs. Land that is not needed for producing food to achieve self-sufficiency of the household can be used to grow other crops for the market. Hence, such surplus land can potentially contribute to household income as typified in Rural World 1 and 2. Households of Rural World 3 that are food deficient and thus face a 'land gap' are less likely to step up to Rural World 2 as they lack land to grow market crops.

Maize is a major staple crop in most action sites and, therefore used in the food self-sufficiency analysis, while soybean has been used as proxy for a rainfed grain legume with a high market potential in the action sites. Opportunities for achieving food self-sufficiency and producing cash crops have been explored using different technology and productivity scenarios. The analysis, therefore, provides insight in the extent to which Rural World 3 farmers that can or cannot step up to Rural World 2 given the available land holding, and it identifies the potential role of agricultural intensification in such development.

2.2 Household survey

Baseline survey data of the N2Africa project was collected in 2010-2011 to provide benchmark information to assess impacts of project interventions at the end of the project (Franke & De Wolf, 2011). Three to five action sites were selected within each country by local experts based on the importance of legumes in farming systems and local diets. The surveys were implemented by experts of the N2Africa project or local consultants. Table 2.1 shows the details of the survey in each country. The survey data was collected according a structured questionnaire facilitating comparison of the results across sites and countries (Appendix I). The collected baseline information covered a range of household characteristics including family composition, education of family members, land holding, sources of income, crops, livestock and nutrition. In total baseline information from approximately 3200 farm households in 29 sites from 8 countries in SSA was collected (Table 2.2).

Table 2.1. Details of the baseline farm household survey carried out within the N2Africa project.

Country	Period of survey	Who did survey	Households selection method
DRC	Aug-Sep 2010	N2Africa	Randomly from administrative lists
Ghana	Sep-Oct 2010	Kwame Nkrumah University of Science & Technology (KNUST)	Randomly in the field
Kenya	Oct-Nov 2010	N2Africa	Randomly in the field
Malawi	Mar-Apr 2011	Bunda College	Randomly in the field
Mozambique	Mar-Apr 2011	N2Africa/Mozambique Institute of Agricultural Research (IIAM)	Randomly from administrative lists
Nigeria	Feb-March 2011	Bayero University Kano (BUK) and IAR-ABU (Kaduna)	Randomly in the field
Rwanda	Oct-Nov 2010	N2Africa	Randomly from administrative lists
Zimbabwe	Jan-Feb 2011	N2Africa	Randomly in the field

2.3 Food self-sufficiency and land gaps

Household food self-sufficiency needs were calculated based on the number of adult equivalents per household and their individual energy needs per year (2500 kcal $capita^{-1}$ day^{-1} times 365 days). Adult equivalent means that energy needs of household members under 18 years are 50% of those of an adult. In the remainder of the report the term adult equivalent is interchangeably used with the term capita. The household food supply was calculated based on the land holding, taking into account two crop cycles per year for relevant action sites (Table 3.1), energy content of grain maize (3570 kcal kg^{-1}) and assuming 20% post-harvest losses. Based on this information the required amount of land for achieving food self-sufficiency for each household was calculated based on the site-specific maize yield (Section 2.5). A shortage of land ('land gap') was calculated for those households unable to produce sufficient maize (energy) to feed household members, and a 'land surplus' for those households that were able to produce beyond household energy needs. The land gap indicates the additional area of land that a household requires to be self-sufficient in maize given site-specific maize yields. Land surplus refers to the area of land that is not required for food self-sufficiency purposes. It is assumed that this area is cropped with soybean to be marketed. We used country-specific soybean yields based on a large number of trials carried out in the N2Africa project (Section 2.5).

Subsequently, a simple economic analysis was carried out based on the gross returns associated with the production of maize for household self-sufficiency and soybean on surplus land. Gross returns for soybean are the difference between yield times price, minus the input costs for seeds (65 kg ha^{-1}; 1.3 times the price of soybean), P fertilizers and inoculum. The maize produced for household self-sufficiency was also valued against market prices but costs for seed and fertilizers were not accounted. Gross returns further do not include costs of family labour or hired labour and thus represent the returns to all labour input related to the production of maize and soybean. Total gross returns of maize and soybean per household are expressed in USD per capita per day and compared with the global poverty benchmark of 1.25 USD $capita^{-1}$ day^{-1}.

2.4 Scenarios

The food self-sufficiency and land gap calculations are done for different intensification scenarios to assess to what extent food self-sufficiency and economic returns of households are affected by production technologies: i) actual yields of maize and soybean (Baseline Scenario); ii) a doubling of actual maize yields and fertilisation of soybean with P fertilizers resulting in higher soybean yields than in the Baseline Scenario (Scenario 2); iii) 80% of simulated water-limited maize yields combined with attainable soybean yields using a combination of P fertilizers and inoculants (Scenario 3). In addition, to assess the sensitivity for soybean prices a scenario was run with a 100% price increase of soybean. It is assumed that in the Baseline Scenario no nitrogen and phosphorus fertilizers are used in both maize and soybean. Because we do not know the amount of nitrogen and phosphorus required to achieve higher maize yields in the other scenarios we do not account for the associated fertilizer costs.

2.5 Yield and price data

The collected information on maize yields in the survey was incomplete or inaccurate because farmer's answers on crop production and land use referred to different cropping cycles. Therefore, farmer's maize yields were based on Monfreda *et al.* (2008), who disaggregated national yield statistics at grid cells of 0.5 x 0.5 arc minute using regional statistics. Because surveyed households in each action site were located in a relatively small area we assigned each action site to one grid cell to derive actual maize yields from the Monfreda database. In addition, weather and soil information (CRU version TS3.20, 2013; FAO, 1996; Batjes, 2006) associated with the same grid cell in each action site was used to simulate water-limited maize yields with the LINPAC model (Jing *et al.*, 2013). This crop model calculates crop biomass as the product of light interception and a crop-specific light use efficiency modified for temperature and light intensity. In this model crop biomass is reduced proportionally to the ratio of actual to potential transpiration when water uptake by the crop is less than crop transpiration demand. We used 80% of the simulated water-limited maize yield as farmer yields commonly tend to plateau around this level because production inputs follow diminishing returns at high yields and because farmers face various climate uncertainties limiting the efficient use of resources (Van Ittersum *et al.*, 2013). For action sites with two crop cycles per year (Table 2.2) the average water-limited yield of both cycles was used in the calculations. Simulated dry matter grain yields are expressed in fresh yield assuming 11% moisture content as used for the actual maize yields (Monfreda *et al.*, 2008). See Appendix II for the maize yields used in the different scenarios.

Information on soybean yields for different production situations was derived from approximately 300 trials per country mainly in the period 2011-2012 (Appendix II). In these trials different technology packages were tested including the current means of production (i.e. no use of external inputs), the use of inoculants, P fertilizer and the combined use of inoculants and P fertilizers. Inoculants are nitrogen-fixing Rhizobium bacteria which are mixed with legume seeds prior to sowing to enhance nitrogen fixation by the host legume crop.

Location-specific prices of harvested crops and P fertilizer were collected in the N2Africa project in June 2013 by different country coordinators at local markets. See Appendix II for the yield and price data used in this study.

2.6 Data limitations and checking

Farm households with missing information on the size of the land holding or the number of household members were excluded from the analyses. Also outlier farm households with extremely large land holdings in relation to the number of family members were excluded from the analysis. Such outliers commonly had more than 10 harvested hectares of land per household member available, which may point at an error in the data or a non-typical farm household. Such outliers were found in South Gem (1), Bondo (2), Kanyamkago (2), Kabare (1), Walungu (1), Ghana North (1) and Kano (1).

Table 2.2 Major agro-ecological and market access characteristics of the action sites where the baseline farm household surveys were conducted.

	Country	Action site	Annual rainfall (mm) [2]	Agro-ecological zone [4]	Number of crop cycles per year	Population density (km-2) [3]	Distance to urban market (h) [1]	Number of households in survey
1	DRC	Kalehe	1826	Tropical cool, humid	2	70	8	45
2	DRC	Kabare	1626	Tropical cool, humid	2	262	2-3	70
3	DRC	Walungu	1613	Tropical cool, humid	2	225	3	106
4	Ghana	Northern region	984	Tropical warm, sub-humid	1	61 - 70	2	124
5	Ghana	Upper East region	1070	Tropical warm, sub-humid	1	56 - 103	1 - 3	151
6	Ghana	Upper West region	985	Tropical warm, sub-humid	1	31 - 40	0.7 - 3	125
7	Kenya	Wamalumu	1754	Tropical cool, humid	2	1200	0.5	100
8	Kenya	South Gem	1314	Tropical cool, humid	2	440	1	100
9	Kenya	Bondo	1314	Tropical cool, humid	2	460	1	100
10	Kenya	Kanyamkago	1202	Tropical cool, humid	2	300	5	100
11	Malawi	Lilongwe	822	Tropical warm, semi-arid	1	250 - 500	0.5 - 2	100
12	Malawi	Dowa	822	Tropical warm, semi-arid	1	100 - 250	2 - 4	97
13	Malawi	Salima	969	Tropical warm, semi-arid	1	129	3 - 4	96
14	Malawi	Ntcheu	1052	Tropical warm, semi-arid	1	128	4	101
15	Mozambique	Mandimba	928	Tropical warm, semi-arid	1	75	< 2	75
16	Mozambique	Gurue	1222	Tropical warm, semi-humid	1	38	< 6	80
17	Mozambique	Sussundenga	949	Tropical warm, semi-arid	1	25	< 4	92
18	Nigeria	Kano state	859	Tropical warm, sub-humid	1	304 - 587	1 - 2	384
19	Nigeria	Northern Kaduna	1040	Tropical warm, sub-humid	1	109 - 129	2 - 3	198
20	Nigeria	Southern Kaduna	1140	Tropical warm, sub-humid	1	37 - 86	3 - 4	199
21	Rwanda	Musambira	957	Tropical cool, humid	2	393	2.5	100
22	Rwanda	Musenyi	957	Tropical cool, humid	2	194	2.5	50
23	Rwanda	Rukara	972	Tropical cool, humid	2	102	3	50
24	Rwanda	Burera	1250	Tropical cool, humid	2	518	5	100
25	Rwanda	Gakenke	1279	Tropical cool, humid	2	456	4	98
26	Zimbabwe	Guruve	789	Tropical warm, semi-arid	1		4	100
27	Zimbabwe	Makoni	863	Tropical warm, semi-arid	1	30	4	97
28	Zimbabwe	Mhondoro	717	Tropical warm, semi-arid	1		2	100
29	Zimbabwe	Mudzi	722	Tropical warm, semi-arid	1		4	98

1) Travel time to a town of more than 50,000 inhabitants.
2) Based on CRU (2013), version CRU TS 3.2, average rainfall in 1981-2010.
3) Based on Uchida and Nelson (2008).
4) Based on IFPRI/Harvest Choice (2009) http://harvestchoice.org/sites/default/files/images/thumbnails/blogs/poverty_agroecological_zones.png

3. Main household characteristics

Figure 3.1 provides information on the monthly rainfall distribution (1981-2010) of the different action sites based on CRU (2013), version CRU TS 3.2 (New *et al.*, 1999).

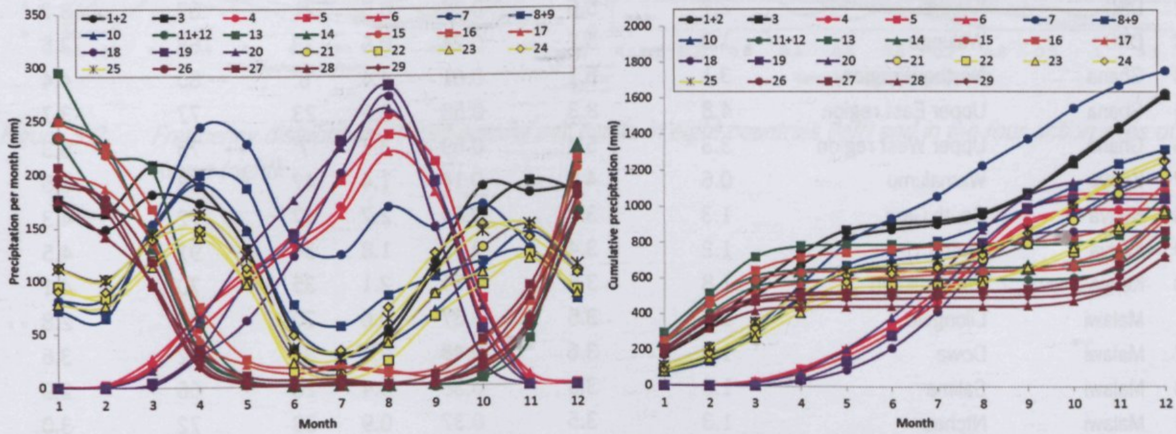


Figure 3.1 *Long-term monthly rainfall (left) and cumulative rainfall (right) in the 29 action sites. See Table 2.2 for the names of the action site with the corresponding legend numbers.*

The action sites in Ghana (red lines) and Nigeria (purple lines) have unimodal rainfall patterns with peaks in August, while in Malawi (green), Zimbabwe (brown) and Mozambique (orange) also have unimodal rainfall patterns with rainfall peaks in January. In Kenya (blue), Rwanda (yellow) and DRC (black) have bimodal rainfall patterns with peaks in March-April and in October-November.

Table 3.1 shows the major household characteristics of the 29 action sites. Land holdings in the action sites of West Africa (Ghana and Nigeria) are larger (> 3 ha) than in the rest of Africa, where in some cases average farms are less than 1 ha (all action sites in Rwanda and Wamalumu in Kenya). Larger land holdings in the action sites of West Africa are associated with larger families and larger livestock holdings. The action sites in West-Africa are also very different in terms of the gender of the household heads: In the majority of the sites 25-30% of the household heads is female but in northern Ghana and Nigeria this percentage is in most action sites less than 10%. Despite the small land holdings in Rwanda approximately 90% of the households depend for at least 75% of their income on farming activities. In contrast, in two action sites of Nigeria (Kano state and Northern Kaduna) only 25% of the surveyed households depend for 75% or more on farming. Another action site in Nigeria, Southern Kaduna, shows more similarities with the other action sites with 80% of the households depending for 75% or more on farming. Action sites with two crop cycles (Kenya, Rwanda and DRC) have on average a more diverse cropping pattern than the action sites with single crop cycles.

Table 3.1 Major characteristics of farm households (FHH) in the different action sites. (TLU = Tropical livestock units of 250 kg).

	Country	Action site	Land holding (ha)	FHH size (capita)	Land availability (ha/cap.)	TLU	% female heads	% FHH with income >75% from farming	Number of crop types
1	DRC	Kalehe	2.2	5.2	0.43	0.3	25	76	4.6
2	DRC	Kabare	2.1	5.6	0.38	0.5	21	67	3.7
3	DRC	Walungu	1.3	5.2	0.25	0.6	33	68	3.5
4	Ghana	Northern region	3.1	5.1	0.61	4.4	6	85	4.4
5	Ghana	Upper East region	4.8	8.3	0.58	3.5	23	77	3.7
6	Ghana	Upper West region	3.3	5.7	0.59	3.7	7	75	5.3
7	Kenya	Wamalumu	0.6	4.2	0.14	1.4	47	58	3.5
8	Kenya	South Gem	1.3	3.8	0.34	2.7	47	72	4.3
9	Kenya	Bondo	1.2	3.4	0.35	1.8	34	91	4.5
10	Kenya	Kanyamkago	1.8	3.6	0.50	2.1	35	70	4.1
11	Malawi	Lilongwe	1.3	3.5	0.37	0.6	20	72	2.8
12	Malawi	Dowa	1.7	3.6	0.48	0.7	31	82	3.6
13	Malawi	Salima	1.3	3.5	0.38	0.4	26	66	2.9
14	Malawi	Ntcheu	1.3	3.5	0.37	0.9	33	72	3.0
15	Mozambique	Mandimba	2.6	3.9	0.65	0.1	12	64	3.9
16	Mozambique	Gurue	2.7	3.6	0.74	0.3	20	61	3.8
17	Mozambique	Sussundenga	3.3	4.4	0.75	1.6	20	59	2.6
18	Nigeria	Kano state	6.9	7.5	0.92	6.1	6	22	4.0
19	Nigeria	Northern Kaduna	3.5	6.1	0.57	2.4	1	26	3.3
20	Nigeria	Southern Kaduna	2.7	4.1	0.65	3.2	8	80	3.9
21	Rwanda	Musambira	0.6	4.0	0.15	0.9	30	85	4.6
22	Rwanda	Musenyi	1.0	3.8	0.27	0.6	28	96	4.8
23	Rwanda	Rukara	0.7	4.1	0.16	0.6	28	92	4.9
24	Rwanda	Burera	0.7	3.5	0.20	0.8	27	92	3.6
25	Rwanda	Gakenke	0.7	3.5	0.21	0.8	23	91	3.9
26	Zimbabwe	Guruve	2.2	3.9	0.55	2.9	33	74	3.2
27	Zimbabwe	Makoni	1.6	3.8	0.42	1.9	40	47	2.9
28	Zimbabwe	Mhondoro	1.9	4.0	0.47	2.1	39	62	2.9
29	Zimbabwe	Mudzi	1.8	4.0	0.44	3.1	23	81	3.1

Availability of crop land per capita is the most important resource indicator to assess food self-sufficiency of farm households and options for cash crop production. Figure 3.1 shows the frequency distribution of land per capita at country level and in the four action sites of Kenya. Especially in Rwanda, DRC and Kenya, a large number of farms is extremely small, in Rwanda almost 50% of the farms have less than 0.1 ha per capita available, in the DRC almost 40% of the farms and in Kenya 25%. Farms in Nigeria, Ghana and Mozambique are relatively large, for example, more than 25% of the farms in Nigeria have more than 1 ha per capita available. This picture of land resource availability when all four action sites in a country are combined obscures the large differences in farm size within the regions as illustrated in the right pane of Figure 3.2. Although at national level approximately 25% of the farms have less than 0.1 ha per capita available, in the action site Wamalumu 50% of the farms are in this class, but only 10% in Kanyamkago. Hence, differences in land resource availability can differ over relatively small spatial scales.

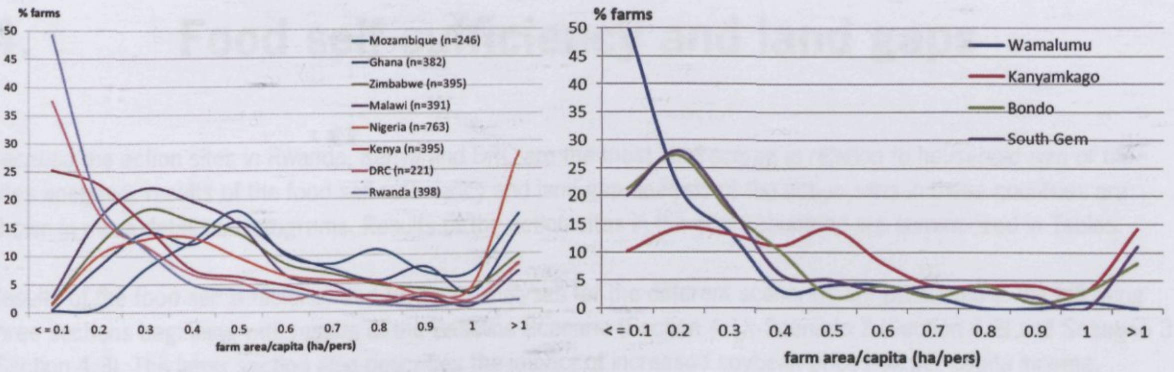


Figure 3.2 *Frequency distribution of land holding per capita in eight countries (left) and in the four action sites of Kenya (right).*

4. Food self-sufficiency and land gaps

Because the action sites in Rwanda, Kenya and DRC are the most land scarce in relation to household size of the sites analysed, results of the food self-sufficiency and land gap analysis of the action sites in these countries are shown in more detail as histograms. Results of the action sites in the other countries are summarized in Tables.

Results of the food self-sufficiency and land gap analyses for the different scenarios are presented in the following three sections beginning with results of the Baseline Scenario (Section 4.1), Scenario 2 (Section 4.2) and Scenario 3 (Section 4.3). The latter section also describes the impact of increased soybean prices on per capita income. Section 4.4 compiles the results of these analyses.

4.1 Baseline Scenario

Figures 4.1, 4.2 and 4.3 show the results of the Baseline Scenario for the action sites in Rwanda, Kenya and DRC, respectively. The data shown for each action site in the Figures 4.1 - 4.3 consists of two associated histograms: On top is the histogram that shows for each farm household (X-axis) the land that is used for achieving self-sufficiency in maize (blue), the 'land gap' or the additional land required for achieving food self-sufficiency (red), and the 'land surplus' or the land available for commercial production of soybean (green). The more households in an action site face a land gap, the more the red columns will dominate the histogram, if many households in an action site have a land surplus the green columns will dominate. The household data is sorted based on the land available for commercial production (from low to high) and the additional land needed for achieving food self-sufficiency (from high to low). Below the 'land' histograms the associated gross returns for the farm households are shown in a similar histogram based on the financial returns of maize produced for self-sufficiency (blue) and the financial returns of soybean produced for the market (green) as described in Section 2.3. The histograms with the gross returns include a horizontal poverty benchmark line of 1.25 USD cap^{-1} day^{1}.

Table 4.1 provides a summary of the most important indicators for all action sites based on this scenario. The average land gap and land surplus relate to the average of farms with a shortage of land to satisfy food self-sufficiency and the average of farms with land available for cash crop production, respectively. Land gap and land surplus are expressed in harvested area, which implies that this area is twice as large as the physical land area in countries with two crop cycles each year, i.e. Kenya, DRC and Rwanda. The column heading '% FHH food self-sufficiency' in Table 4.1 corresponds with the proportion of farm households in an action site that has a land surplus. Hence, the remaining proportion of the farm households is not food self-sufficient and has a land gap. For example, in the case of Kabare (DRC) 51% of the farm households is food self-sufficient and these households have an average (harvested) land surplus of 4.91 ha. The remaining 49% of the households is not food self-sufficient and face an average land gap of 1.25 ha.

Table 4.1 Summary of key indicators of the food self-sufficiency analyses in the Baseline Scenario. The average land gap and land surplus relate to the average of farms with a shortage of land to satisfy food self-sufficiency and the average of farms with land available for cash crop production, respectively. FHH=farm household.

	Country	Action site	% FHH food self-sufficient	% FHH > 1.25 USD cap^{-1} day^{-1}	Average land gap (ha FHH^{-1})	Average land surplus (ha FHH^{-1})
1	DRC	Kalehe	62	38	0.97	4.45
2	DRC	Kabare	51	28	1.25	4.91
3	DRC	Walungu	32	19	1.46	4.83
4	Ghana	Northern region	78	29	0.58	2.25
5	Ghana	Upper East region	87	33	0.57	3.19
6	Ghana	Upper West region	78	37	0.62	2.13
7	Kenya	Wamalumu	54	1	0.47	1.05
8	Kenya	South Gem	85	15	0.36	2.14
9	Kenya	Bondo	82	14	0.29	2.08
10	Kenya	Kanyamkago	89	23	0.42	3.16
11	Malawi	Lilongwe	58	4	0.36	0.89
12	Malawi	Dowa	74	10	0.20	1.32
13	Malawi	Salima	78	2	0.27	0.78
14	Malawi	Ntcheu	69	5	0.33	0.68
15	Mozambique	Mandimba	92	8	0.34	1.51
16	Mozambique	Gurue	81	13	0.55	1.55
17	Mozambique	Sussundenga	97	12	0.44	2.25
18	Nigeria	Kano state	70	42	0.87	6.83
19	Nigeria	Northern Kaduna	95	16	0.82	2.26
20	Nigeria	Southern Kaduna	89	25	0.38	2.02
21	Rwanda	Musambira	11	5	1.44	1.93
22	Rwanda	Musenyi	44	12	1.45	1.81
23	Rwanda	Rukara	20	6	1.47	2.18
24	Rwanda	Burera	41	14	1.42	1.74
25	Rwanda	Gakenke	43	11	1.40	1.76
26	Zimbabwe	Guruve	91	32	0.36	1.59
27	Zimbabwe	Makoni	31	10	0.97	1.17
28	Zimbabwe	Mhondoro	94	30	0.13	1.47
29	Zimbabwe	Mudzi	93	18	0.13	1.16

In the Baseline Scenario, farm households especially in the action sites of Rwanda, DRC, Kenya (Wamalumu) and Zimbabwe (Makoni) face problems in satisfying own food requirements. In general, less than 50% of the farm households in these action sites are food self-sufficient. Current maize yields of Musambira (Rwanda) and especially Makoni (Zimbabwe) are very low compared to the other action sites in Rwanda and Zimbabwe (Appendix II). Therefore, Musambira and Makoni stand out compared with the other action sites in Rwanda and Zimbabwe, respectively.

The extent of households that is able to satisfy own food needs is most clearly visualized in Figure 4.1 for the action site Musambiro (Rwanda). The red area in Figure 4.1 indicates the land gap or the additional land requirements to satisfy household food needs in Musambiro given current maize yields. The green area in Figure 4.1 provides the land area of farm households available for growing soybeans. Only 11% of the households in Musambiro have such surplus land (Figure 4.1; Table 4.1). In the action sites of Kenya the red area is smaller indicating that more farm households are food self-sufficient than in Rwanda (Figure 4.2). The action sites in the DRC take an intermediate position in terms of achieving food self-sufficiency (Figure 4.3).

Since gross returns from maize and soybean are both expressed in USD cap^{-1} day^{-1} the gross return from maize is the same for those households that satisfy own food needs in Figures 4.1 to 4.3. For households that are not self-sufficient in maize the gross return per capita varies, but remains below the level of food self-sufficient households. In general, gross returns from maize are less than 25% of the poverty benchmark for food self-sufficient households. The majority of the total gross returns is derived from soybean if farm households have land surplus.

Overall gross returns from agriculture (maize and soybean production) are low in the Baseline Scenario (Table 4.1). In Kano state (Nigeria) about 40% of the households is able to earn 1.25 USD cap^{-1} day^{-1}, but in most other action sites this percentage is much lower, even as low as 1% in Wamalumu (Kenya). In general, the action sites of Rwanda and Malawi score low on reaching the poverty benchmark. Rwanda sites score low because of the restricted land availability for commercial soybean production. Food self-sufficiency is better in the Malawi sites, but the ,elatively low soybean yields and low prices of soybean and maize result in low gross returns (Appendix II). Malawi contrasts with the action sites in the DRC, where a larger proportion of the households is not food self-sufficient (compared with Malawi). But because of higher soybean yields and higher soybean and maize prices in the DRC a larger proportion of the households with a land surplus can earn more than the poverty benchmark.

In general, the average land surplus per farm is larger than the average land gap per farm. Action sites in Rwanda and the DRC have the largest land gap with 1 - 1.5 ha per household, which corresponds with 0.5 - 0.75 ha farm land in these countries with two crop cycles per year.

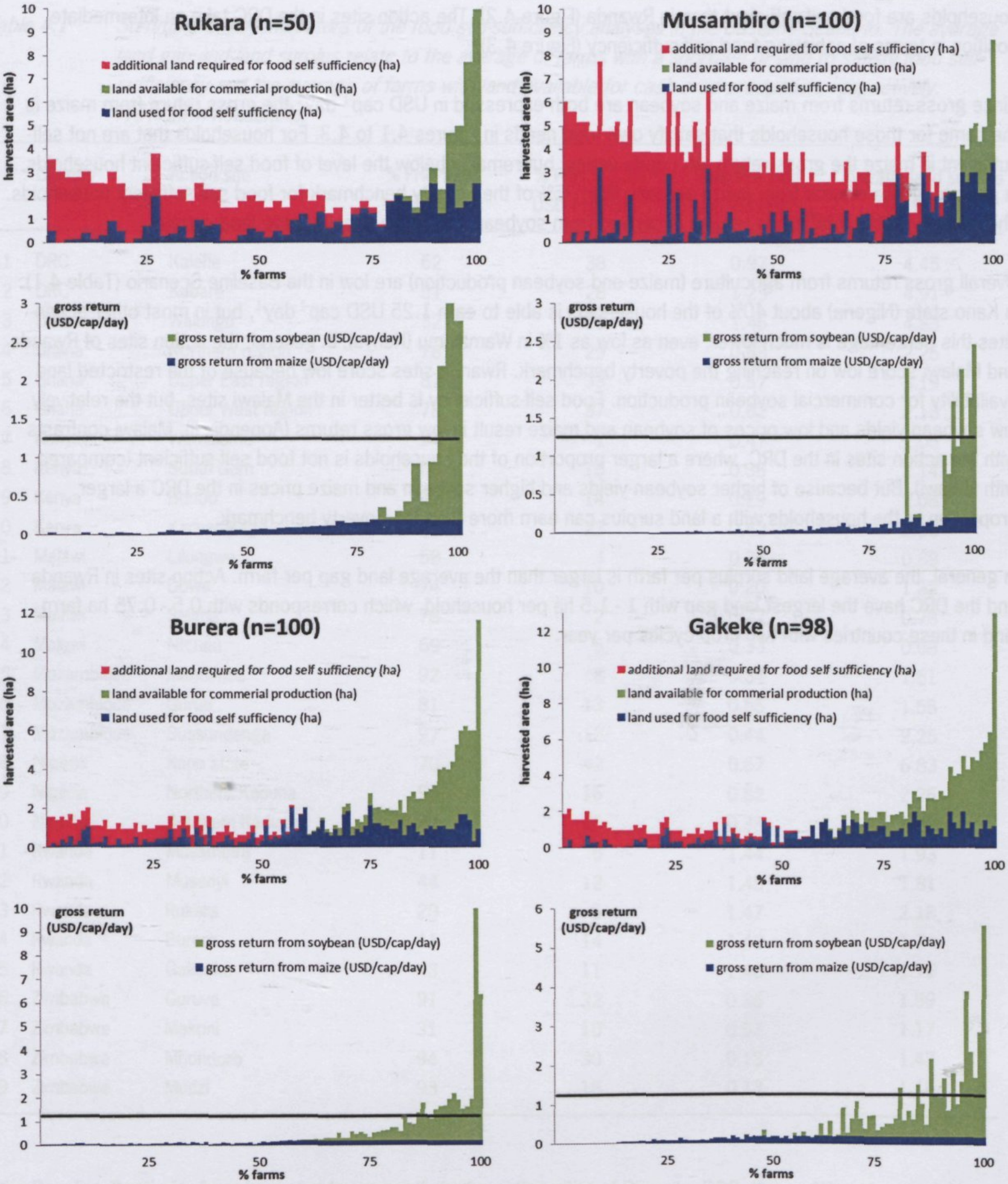


Figure 4.1 *Food self-sufficiency and land gap analysis in the Baseline Scenario based on two cropping seasons for four action sites in Rwanda (results of Musenyi in the South of Rwanda not shown, but similar to the Rukara site). For each action site on top the food-self-sufficiency analysis based on current maize yields. For each site at the bottom the associated gross returns from growing soybean (current yields) on surplus land (green area) and the self-consumed maize valued using prevailing market prices (blue area). The black horizontal line indicates the poverty benchmark of 1.25 USD cap* $^{-1}$ *day* $^{-1}$.

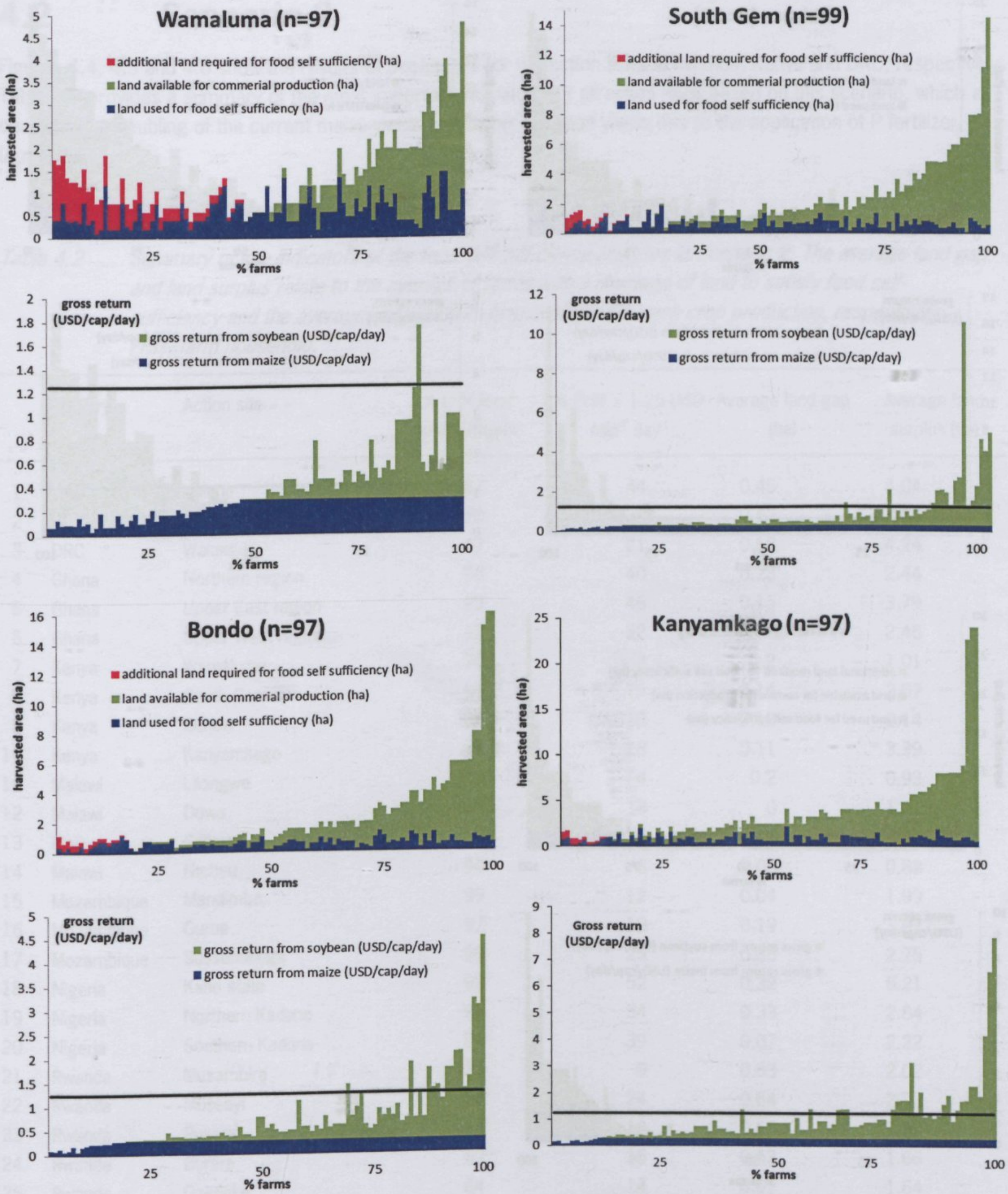


Figure 4.2 *Food self-sufficiency and land gap analysis in the Baseline Scenario based on two cropping seasons for four action sites in Kenya. For each action site on top the food-self-sufficiency analysis based on current maize yields. For each site at the bottom the associated gross returns from growing soybean (current yields) on surplus land (green area) and the self-consumed maize valued using prevailing market prices (blue area). The black horizontal line indicates the poverty benchmark of 1.25 USD cap $^{-1}$ day $^{-1}$.*

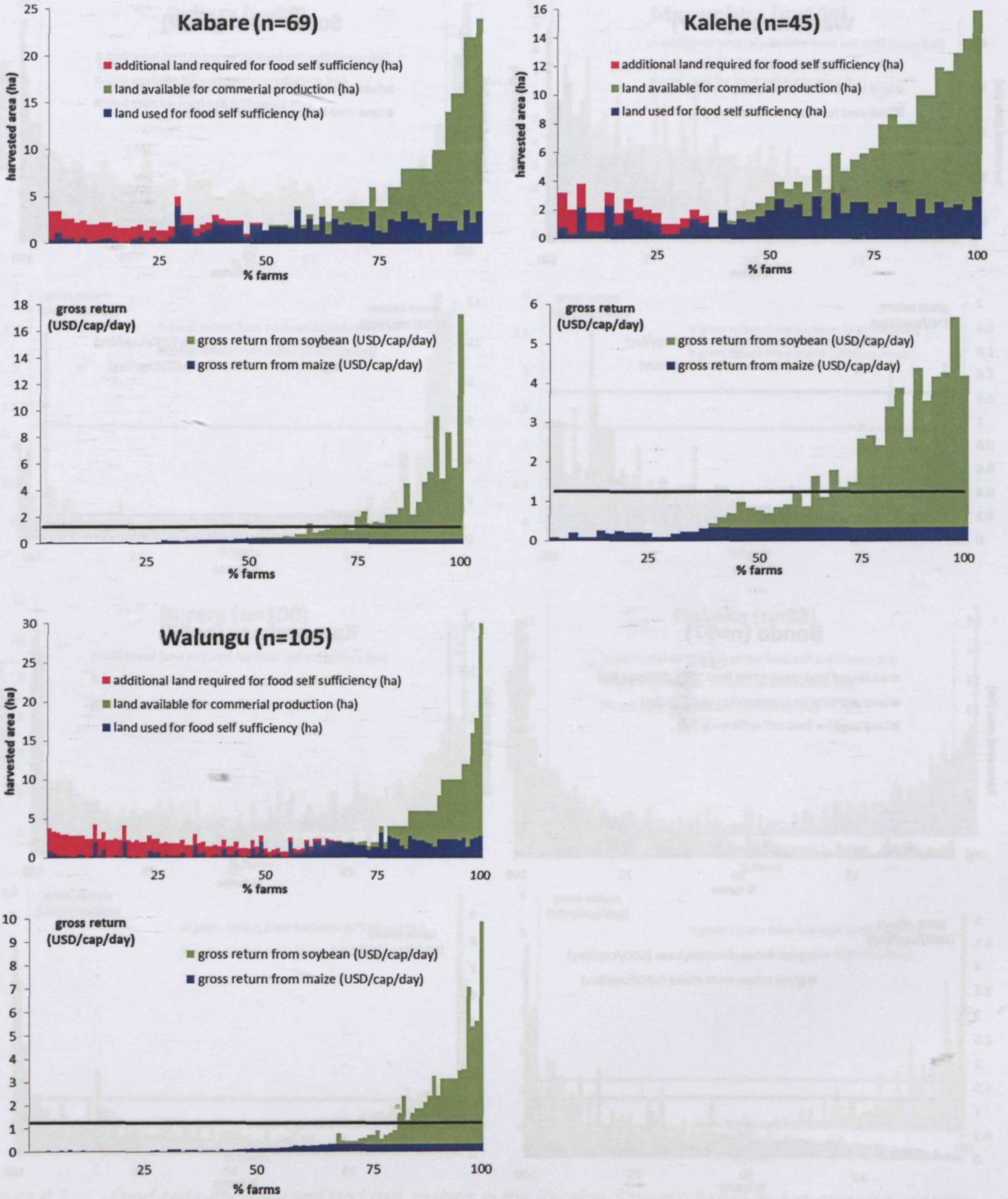


Figure 4.3 Food self-sufficiency and land gap analysis in the Baseline Scenario based on two cropping seasons for three action sites in DRC. For each action site on top the food-self-sufficiency analysis based on current maize yields. For each site at the bottom the associated gross returns from growing soybean (current yields) on surplus land (green area) and the self-consumed maize valued using prevailing market prices (blue area). The black horizontal line indicates the poverty benchmark of 1.25 USD cap $^{-1}$ day $^{-1}$.

4.2 Scenario 2

Figures 4.4, 4.5 and 4.6 show the results of Scenario 2 for the action sites in Rwanda, Kenya and DRC, respectively. Table 4.2 provides a summary of the most important indicators for all action sites based on this scenario, which consists of a doubling of the current maize yields and higher soybean yields due to the application of P fertilizer (Appendix II).

Table 4.2 Summary of key indicators of the food self-sufficiency analyses in Scenario 2. The average land gap and land surplus relate to the average of farms with a shortage of land to satisfy food self-sufficiency and the average of farms with land available for cash crop production, respectively. FHH=farm household.

	Country	Action site	% FHH food self-sufficient	% FHH > 1.25 USD cap^{-1} day^{1}	Average land gap (ha)	Average land surplus (ha)
1	DRC	Kalehe	87	44	0.45	4.04
2	DRC	Kabare	70	35	0.62	4.58
3	DRC	Walungu	47	21	0.68	4.24
4	Ghana	Northern region	96	40	0.23	2.44
5	Ghana	Upper East region	99	46	0.15	3.79
6	Ghana	Upper West region	98	52	0.35	2.46
7	Kenya	Wamalumu	79	3	0.2	1.01
8	Kenya	South Gem	95	19	0.14	2.07
9	Kenya	Bondo	94	19	0.12	2.14
10	Kenya	Kanyamkago	95	28	0.11	3.39
11	Malawi	Lilongwe	90	4	0.2	0.93
12	Malawi	Dowa	100	13	0	1.31
13	Malawi	Salima	97	2	0.19	0.96
14	Malawi	Ntcheu	94	6	0.08	0.88
15	Mozambique	Mandimba	99	12	0.04	1.99
16	Mozambique	Gurue	97	19	0.19	1.97
17	Mozambique	Sussundenga	99	25	0.38	2.75
18	Nigeria	Kano state	92	52	0.32	6.21
19	Nigeria	Northern Kaduna	98	34	0.33	2.84
20	Nigeria	Southern Kaduna	99	39	0.07	2.22
21	Rwanda	Musambira	20	9	0.63	2.02
22	Rwanda	Musenyi	56	24	0.64	2.33
23	Rwanda	Rukara	38	10	0.63	1.82
24	Rwanda	Burera	59	16	0.63	1.66
25	Rwanda	Gakenke	64	14	0.61	1.64
26	Zimbabwe	Guruve	97	60	0.21	1.85
27	Zimbabwe	Makoni	72	23	0.40	1.04
28	Zimbabwe	Mhondoro	100	45	0	1.64
29	Zimbabwe	Mudzi	100	38	0	1.43

The impact of higher maize yields and soybean yields in this scenario compared with the Baseline Scenario is twofold: First, higher maize yields imply that less land is required for achieving food self-sufficiency of households, hence more surplus land is available for growing soybean. Second, the increased soybean yields give higher gross returns from surplus land. But because the change in soybean yields and associated costs for P fertilizers are action-site-specific the outcome for household income is not the same for each action site.

In many action sites most farm households are food self-sufficient after doubling maize yields from the actual level, but approximately 50% of the households in the action sites in Rwanda and Walungu (DRC) remain unable to produce sufficient food to meet their household needs. Musambira (Rwanda) is a negative outlier due to very poor current maize yields (Appendix II). Figures 4.4 - 4.6 tell the same story in detail for the action sites of Rwanda, Kenya and DRC, respectively: The red area decreases in this scenario compared with the Baseline Scenario but changes are overall modest. Similarly, the green area in Figures 4.4 - 4.6 increases but also here changes are modest.

With the decrease in the number of households that are not food self-sufficient also the land gap decreases to zero in action sites where all farm households are self-sufficient to approximately 0.6 ha in land scarce action sites. The average land surplus in this scenario can decrease compared with the Baseline Scenario (e.g. in DRC) because more households contribute to the average value but only with small land areas reducing the overall average land surplus. Associated with the smaller land gap and associated partly with the higher soybean yields the number of households that is able to earn more than 1.25 USD $capita^{-1}$ day^{-1} increases. However, only in three of the 29 action sites (Upper West region, Ghana; Kano state, Nigeria; Guruve, Zimbabwe) more than 50% of the households is able to reach this income level. Higher soybean yields contribute partly to the higher percentage of households earning more than 1.25 USD $capita^{-1}$ day^{-1}, because high fertilizer costs outweigh the yield increase due to fertilizer use in some countries: In the DRC, Malawi and Rwanda gross returns per hectare soybean are therefore less in Scenario 2 than in the Baseline Scenario.

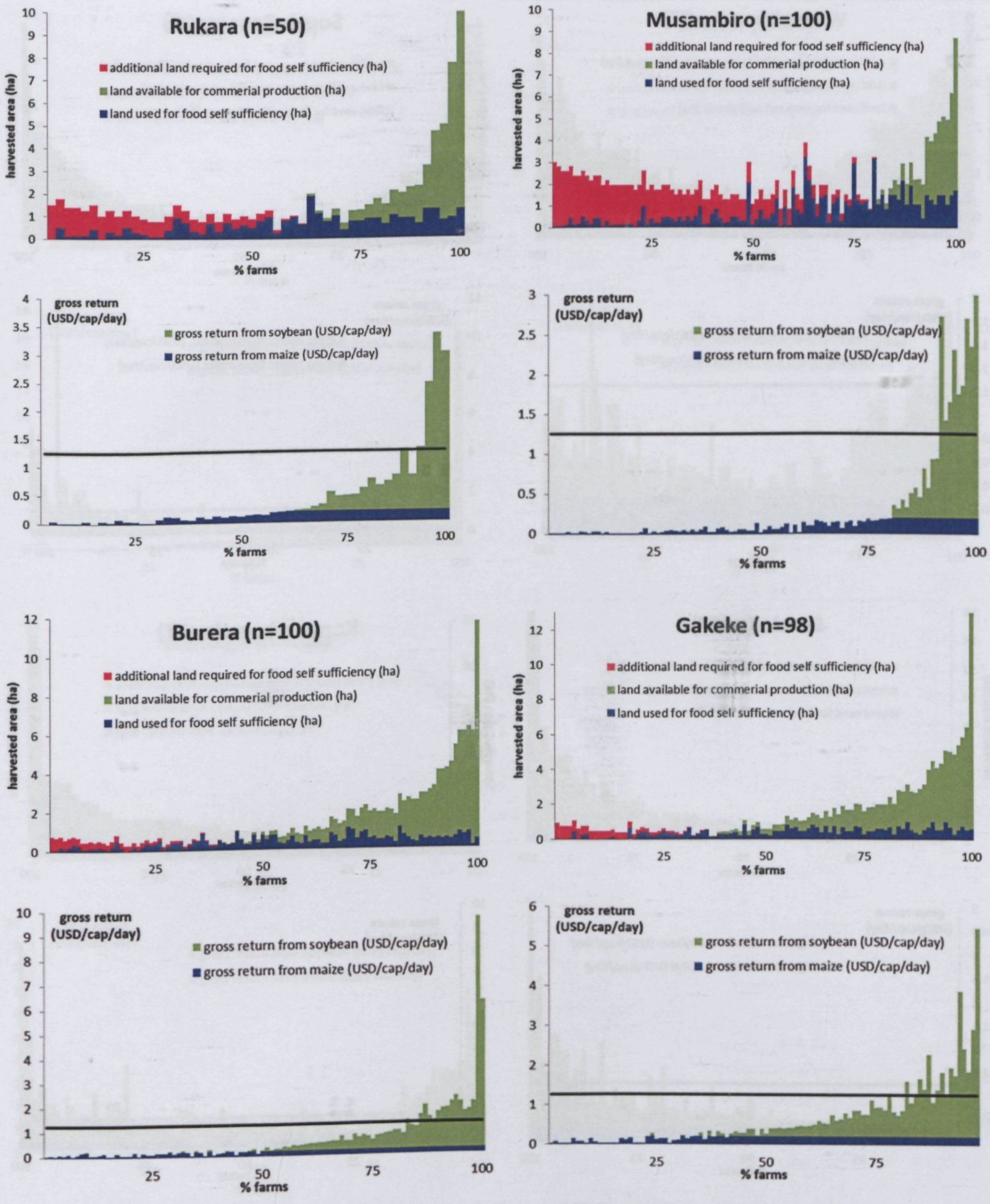


Figure 4.4 *Food self-sufficiency and land gap analysis in Scenario 2 based on two cropping seasons for four action sites in Rwanda (Action site Musenyi in the South not shown, but similar to the Rukara site). For each action site on top the food-self-sufficiency analysis based on twice the current maize yields. For each site at the bottom the associated gross returns from growing soybean (+ P fertilizer) on surplus land (green area) and the self-consumed maize valued using prevailing market prices (blue area). The black horizontal line indicates the poverty benchmark of 1.25 USD cap*$^{-1}$ *day*$^{-1}$.

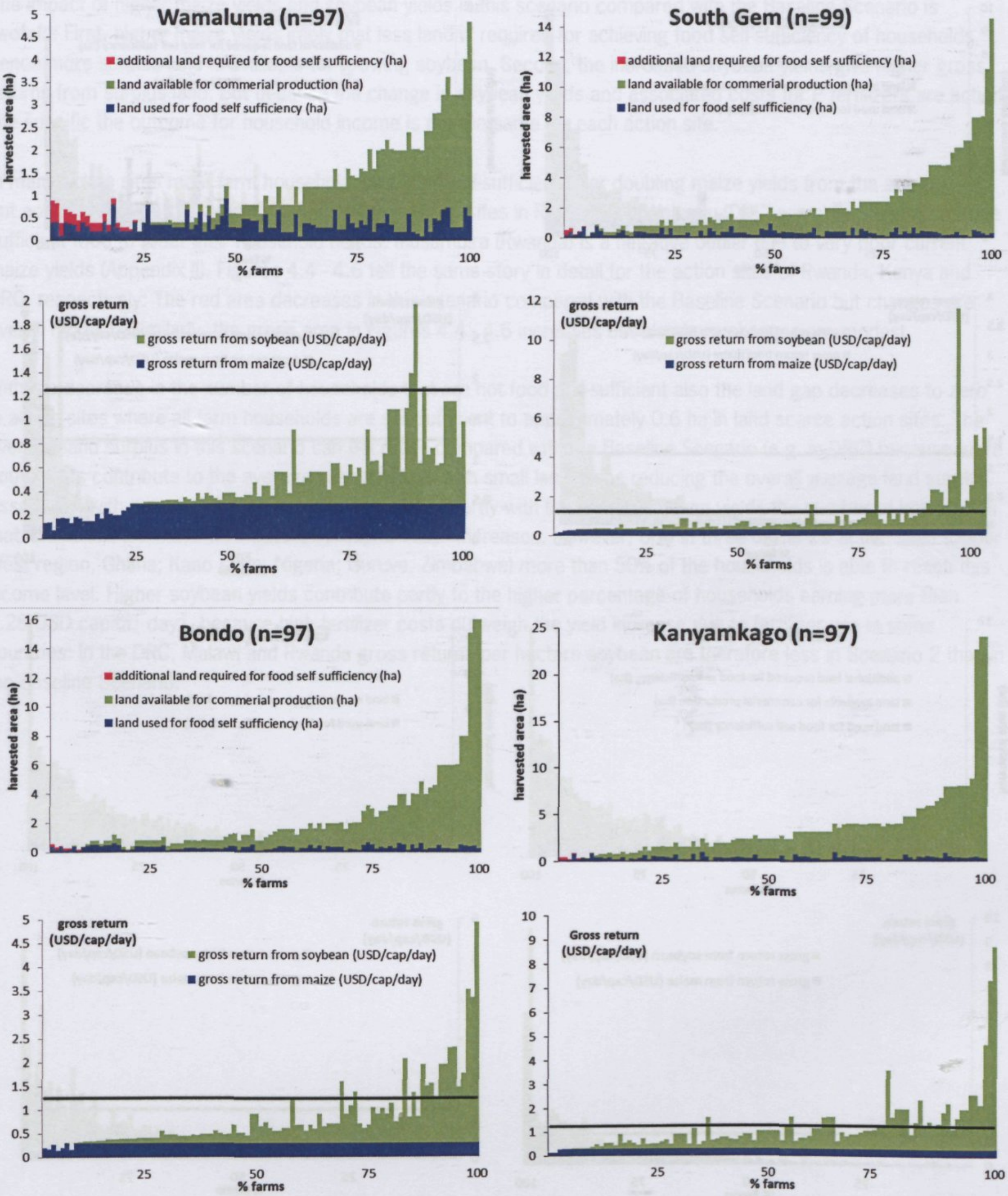


Figure 4.5 *Food self-sufficiency and land gap analysis in Scenario 2 based on two cropping seasons for four action sites in Kenya. For each action site on top the food-self-sufficiency analysis based on twice the current maize yields. For each site at the bottom the associated gross returns from growing soybean (+ P fertilizer) on surplus land (green area) and the self-consumed maize valued using prevailing market prices (blue area). The black horizontal line indicates the poverty benchmark of 1.25 USD cap $^{-1}$ day $^{-1}$.*

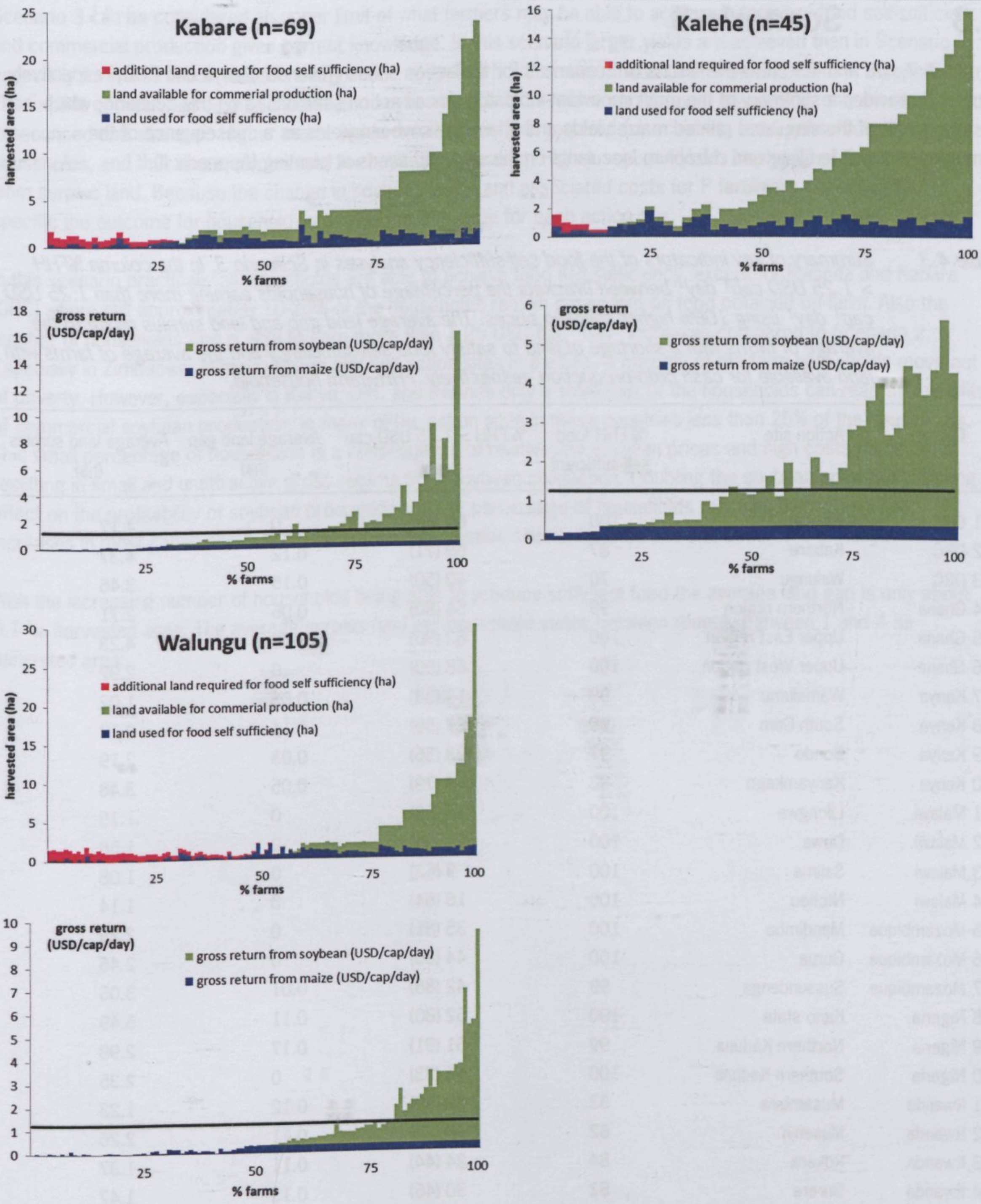


Figure 4.6 *Food self-sufficiency and land gap analysis in Scenario 2 based on two cropping seasons for three action sites in DRC. For each action site on top the food-self-sufficiency analysis based on twice the current maize yields. For each site at the bottom the associated gross returns from growing soybean (+ P fertilizer) on surplus land (green area) and the self-consumed maize valued using prevailing market prices (blue area). The black horizontal line indicates the poverty benchmark of 1.25 USD cap $^{-1}$ day $^{-1}$.*

4.3 Scenario 3

Figures 4.7, 4.8 and 4.9 show the results of Scenario 3 for the action sites in Rwanda, Kenya and DRC, respectively. Table 4.3 provides a summary of the most important indicators for all action sites based on this scenario, which is based on 80% of the simulated rainfed maize yields and attainable soybean yields as a consequence of the combined use of P fertilizer and rhizobium inoculants on the soybean seeds at planting (Appendix II).

Table 4.3 Summary of key indicators of the food self-sufficiency analyses in Scenario 3. In the column %FHH > 1.25 USD cap^{-1} day^{-1} between brackets the percentage of households earning more than 1.25 USD cap^{-1} day^{-1} using 100% higher soybean prices. The average land gap and land surplus relate to the average of farms with a shortage of land to satisfy food self-sufficiency and the average of farms with land available for cash crop production, respectively. FHH=farm household.

Country	Action site	% FHH food self-sufficient	% FHH > 1.25 USD cap^{-1} day^{-1}	Average land gap (ha)	Average land surplus (ha)
1 DRC	Kalehe	100	64 (87)	0	4.17
2 DRC	Kabare	87	59 (71)	0.12	4.37
3 DRC	Walungu	70	40 (50)	0.15	3.46
4 Ghana	Northern region	99	54 (80)	0.06	2.71
5 Ghana	Upper East region	100	62 (90)	0	4.23
6 Ghana	Upper West region	100	68 (90)	0	2.92
7 Kenya	Wamalumu	99	13 (38)	0.05	1.02
8 Kenya	South Gem	99	27 (59)	0.14	2.12
9 Kenya	Bondo	97	23 (56)	0.03	2.19
10 Kenya	Kanyamkago	98	44 (79)	0.05	3.48
11 Malawi	Lilongwe	100	14 (52)	0	1.15
12 Malawi	Dowa	100	24 (64)	0	1.56
13 Malawi	Salima	100	9 (63)	0	1.08
14 Malawi	Ntcheu	100	16 (64)	0	1.14
15 Mozambique	Mandimba	100	35 (81)	0	2.29
16 Mozambique	Gurue	100	44 (85)	0	2.46
17 Mozambique	Sussundenga	99	42 (86)	0.01	3.05
18 Nigeria	Kano state	100	62 (80)	0.11	6.49
19 Nigeria	Northern Kaduna	99	51 (91)	0.17	2.98
20 Nigeria	Southern Kaduna	100	56 (83)	0	2.35
21 Rwanda	Musambira	83	20 (40)	0.12	1.23
22 Rwanda	Musenyi	82	46 (62)	0.11	2.26
23 Rwanda	Rukara	84	24 (44)	0.11	1.37
24 Rwanda	Burera	82	30 (46)	0.13	1.47
25 Rwanda	Gakenke	82	33 (53)	0.12	1.58
26 Zimbabwe	Guruve	99	74 (92)	0.02	2.05
27 Zimbabwe	Makoni	99	54 (84)	0.01	1.49
28 Zimbabwe	Mhondoro	100	56 (84)	0	1.77
29 Zimbabwe	Mudzi	100	51 (86)	0	1.48

Scenario 3 can be considered an upper limit of what farmers may be able to achieve in terms of food self-sufficiency and commercial production given current knowledge. In this scenario larger yields are achieved than in Scenario 2, especially for maize which yields in many action sites 4 to 5 times more than in the Baseline Scenario (Appendix II). The impact of these higher maize yields and soybean yields is therefore similar as in Scenario 2, only more pronounced and stronger: Higher maize yields result in less land required for achieving food self-sufficiency of households, and thus more surplus land for soybean cultivation. Higher soybean yields imply higher gross returns from surplus land. Because the change in soybean yields and associated costs for P fertilizers are action-site specific the outcome for household income is not the same for each action site.

In this scenario practically all households are able to achieve food self-sufficiency, except for Rwanda and Kabare (DRC) where still approximately 10-20% of the households remain dependent on food obtained off-farm. Also the number of households that is able to earn more than 1.25 USD cap^{-1} day^{-1} increases compared to Scenario 2. Especially in Zimbabwe, Nigeria, Ghana and two action sites in the DRC a majority of the farm households move out of poverty. However, especially in Kenya, DRC and Rwanda only a small part of the households can reap the benefits of commercial soybean production: In many of the action sites in these countries less than 25% of the households. This small percentage of households is a consequence of relative low soybean prices and high costs for fertilizer resulting in small and unattractive gross returns from soybean production. Doubling the soybean price has a strong effect on the profitability of soybean production and the percentage of households reaching the poverty line increases in most cases above 50%, except for three action sites in Rwanda and one action site in Kenya.

With the increasing number of households being able to produce sufficient food the average land gap is only about 0.1 ha harvested area. The average surplus land per household varies between roughly between 1 and 4 ha harvested area.

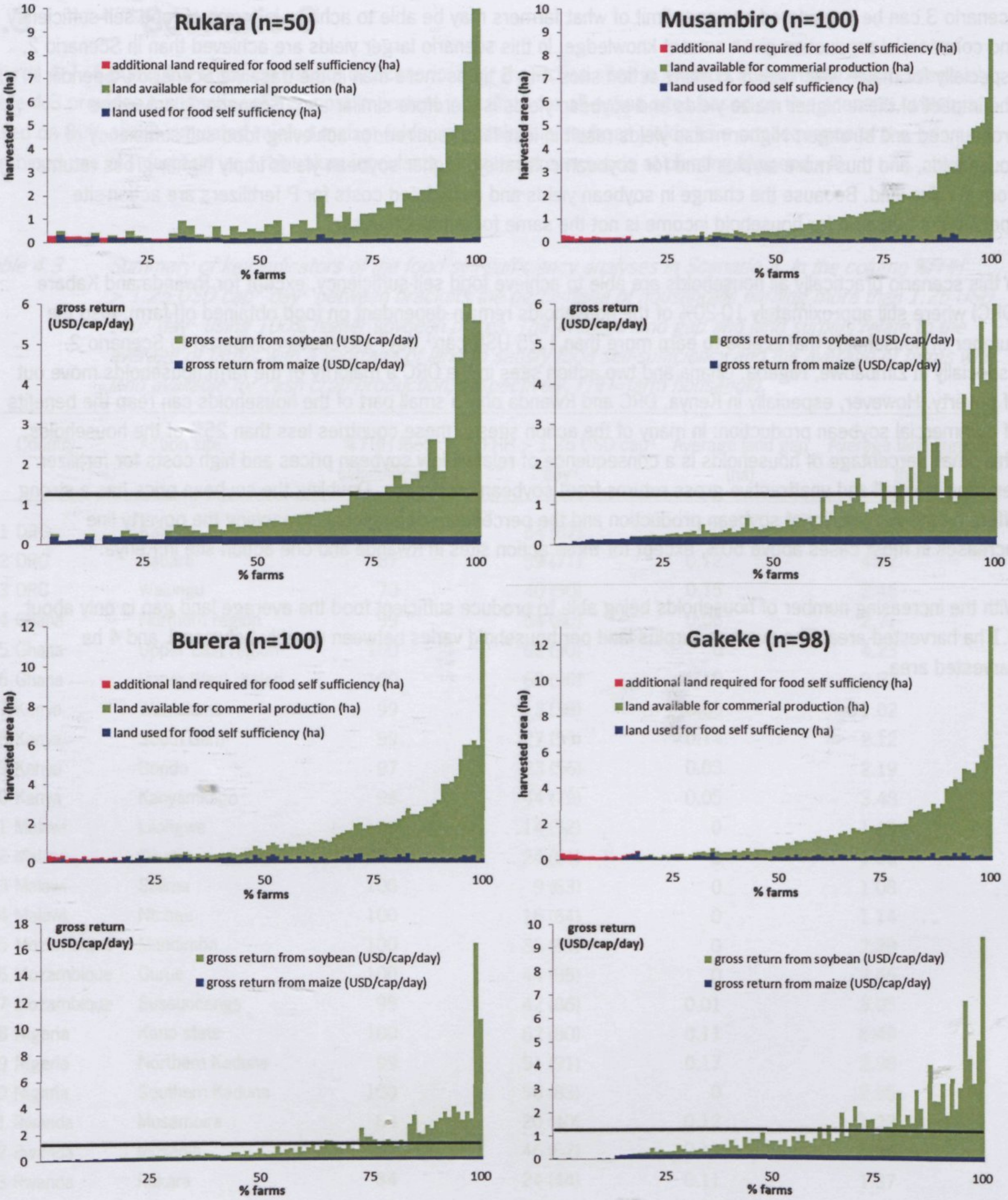


Figure 4.7 *Food self-sufficiency and land gap analysis in Scenario 3 based on two cropping seasons for four action sites in Rwanda (Action site Musenyi in the South not shown, but very similar to the Rukara site). For each action site on top the food-self-sufficiency analysis based 80% water-limited maize yields. For each site at the bottom the associated gross returns from growing soybean (P fertilizer + inoculants) on surplus land (green area) and the self-consumed maize valued using prevailing market prices (blue area). The black horizontal line indicates the poverty benchmark of 1.25 USD cap^{-1} day^{-1}.*

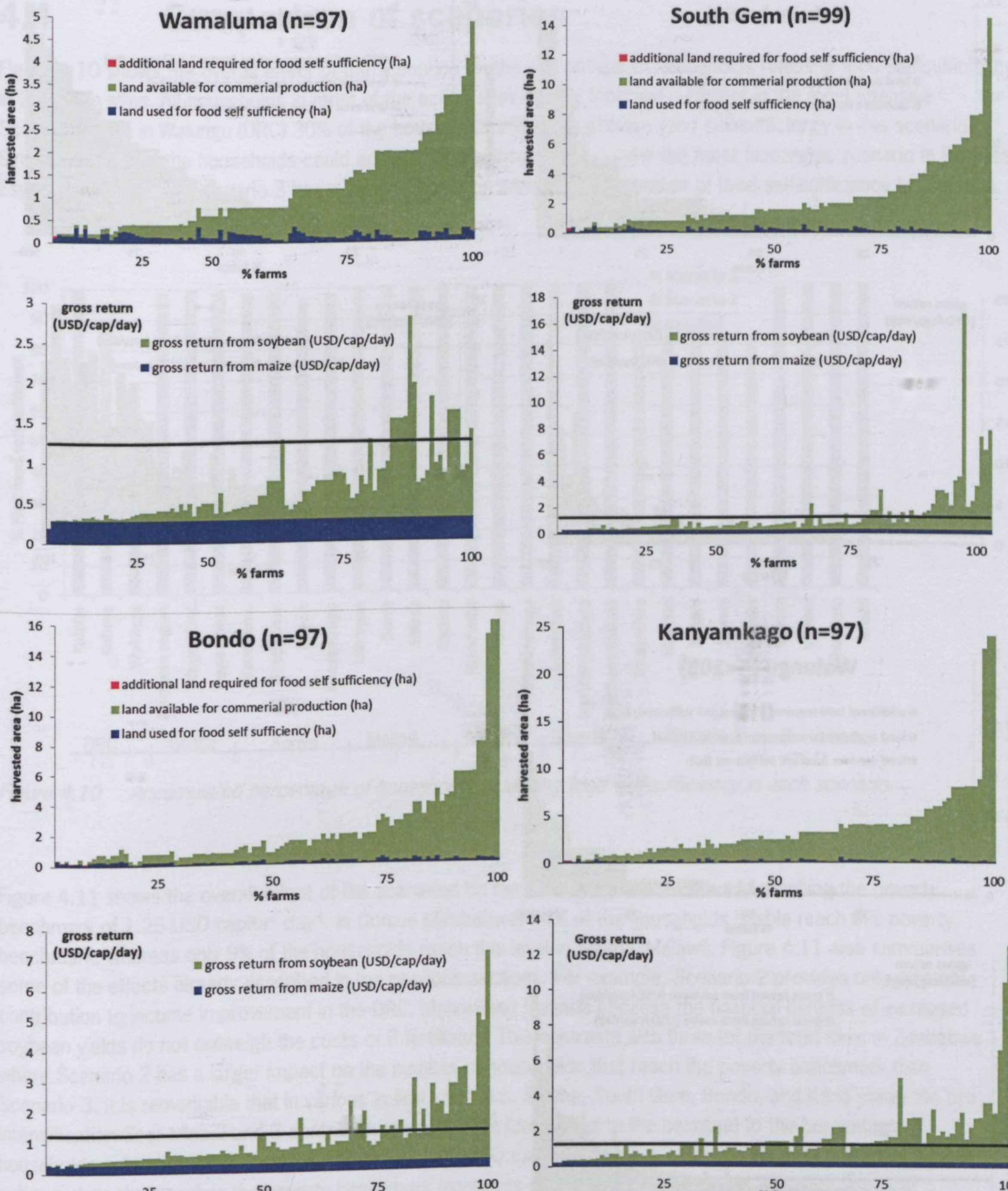


Figure 4.8 *Food self-sufficiency and land gap analysis in Scenario 3 based on two cropping seasons for four action sites in Kenya. For each action site on top the food-self-sufficiency analysis based 80% water-limited maize yields. For each site at the bottom the associated gross returns from growing soybean (P fertilizer + inoculants) on surplus land (green area) and the self-consumed maize valued using prevailing market prices (blue area). The black horizontal line indicates the poverty benchmark of 1.25 USD cap* $^{-1}$ *day* $^{-1}$.

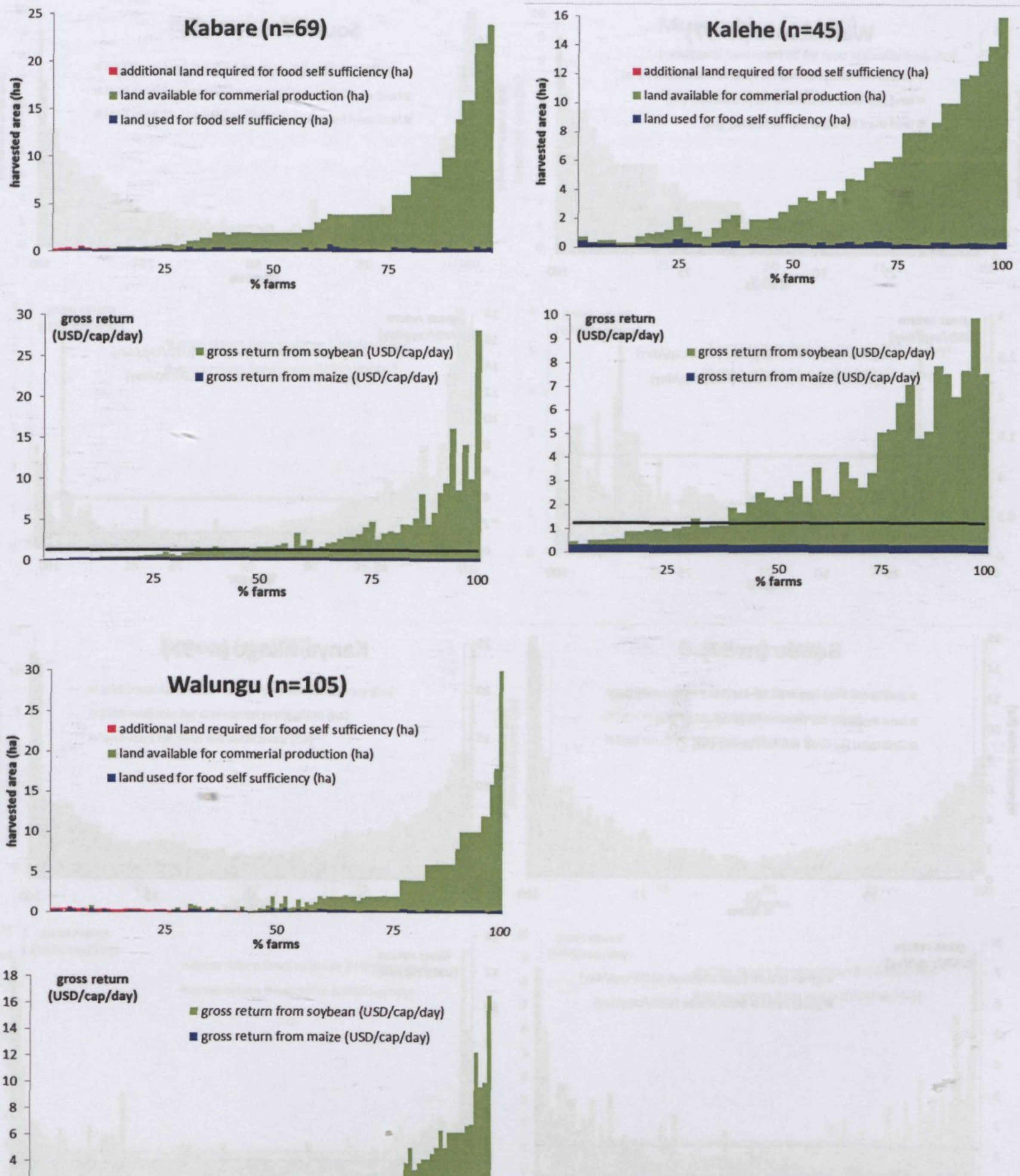


Figure 4.9 *Food self-sufficiency and land gap analysis in Scenario 3 based on two cropping seasons for four action sites in DRC. For each action site on top the food-self-sufficiency analysis based 80% water-limited maize yields. For each site at the bottom the associated gross returns from growing soybean (P fertilizer + inoculants) on surplus land (green area) and the self-consumed maize valued using prevailing market prices (blue area). The black horizontal line indicates the poverty benchmark of 1.25 USD cap $^{-1}$ day $^{-1}$.*

4.4 Comparison of scenarios

Figure 4.10 shows the overall effect of the scenarios on the percentage of households reaching food self-sufficiency in 29 action sites. All households in most of the action sites can be food self-sufficient in the most intensive Scenario 3, but in Walungu (DRC) 30% of the households still fail to achieve food self-sufficiency in this scenario. Similarly, not all of the households could achieve food self-sufficiency under the most favourable scenario in Rwanda. Especially in Rwanda, Scenario 3 has a strong impact on improving the number of food self-sufficiency households.

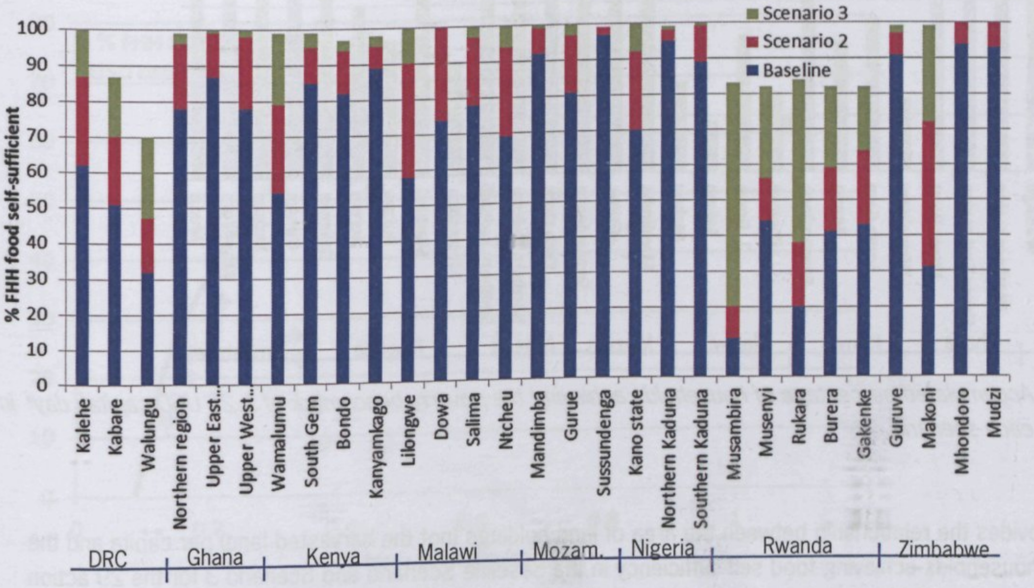


Figure 4.10 Accumulated percentage of households achieving food self-sufficiency in each scenario.

Figure 4.11 shows the overall effect of the scenarios on the percentage of households reaching the poverty benchmark of 1.25 USD capita^{-1} day^{-1}. In Guruve (Zimbabwe) 74% of the households is able reach this poverty benchmark, whereas only 9% of the households reach this level in Salima (Malawi). Figure 4.11 also summarises some of the effects already described in the previous sections. For example, Scenario 2 provides only a small contribution to income improvement in the DRC, Malawi and Rwanda because the financial benefits of increased soybean yields do not outweigh the costs of P fertilizers. This contrasts with three (of the four) sites in Zimbabwe where Scenario 2 has a larger impact on the number of households that reach the poverty benchmark than Scenario 3. It is remarkable that in various action sites (a.o. Kalehe, South Gem, Bondo, and Kano state) the two intensification Scenarios 2 and 3 contribute relatively little (compared to the baseline) to the percentage of households achieving the poverty benchmark of 1.25 USD capita^{-1} day^{-1}. For example, the percentage of households in Kano state that reaches the poverty benchmark increases only with 20% in the most intensive Scenario 3 compared with 40% of the households reaching this level in the Baseline Scenario. The relative small contribution of intensification is associated with low economic returns of soybean and especially the skewed distribution of land holdings in action sites. Because even action sites with on average large land holdings such as Kano state show relatively little impact of intensification on poverty reduction. This indicates at the limitations of agricultural intensification for reducing poverty of farms household even for regions with relatively large land holdings.

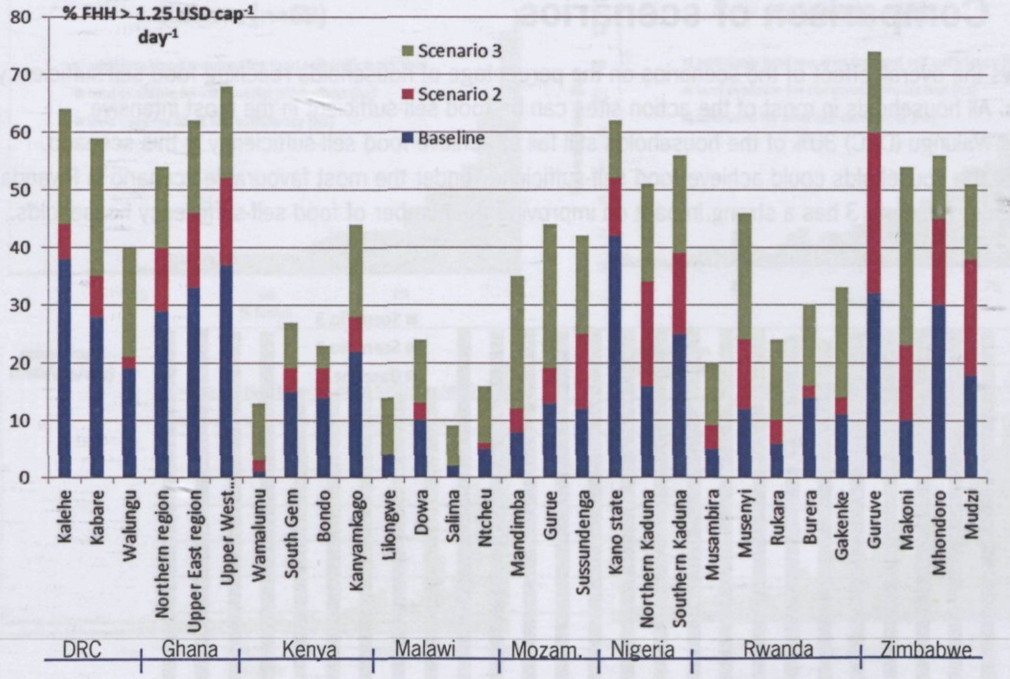


Figure 4.11 Accumulated percentage of households achieving the poverty benchmark of 1.25 USD capita[1] day[1] in each scenario.

Figure 4.12 provides the relationship between the area of land holdings (not the harvested land) per capita and the percentage of households achieving food self-sufficiency in the Baseline Scenario and Scenario 3 for the 29 action sites. The line in Figure 4.12 provides an upper boundary for the percentage of households that is able to reach food self-sufficiency in the Baseline Scenario. The green markers of Scenario 3 in Figure 4.12 are mostly lying above this upper boundary indicating the impacts of agricultural intensification on achieving food self-sufficiency. Only two action sites of the DRC are clearly below this boundary line in Scenario 3.

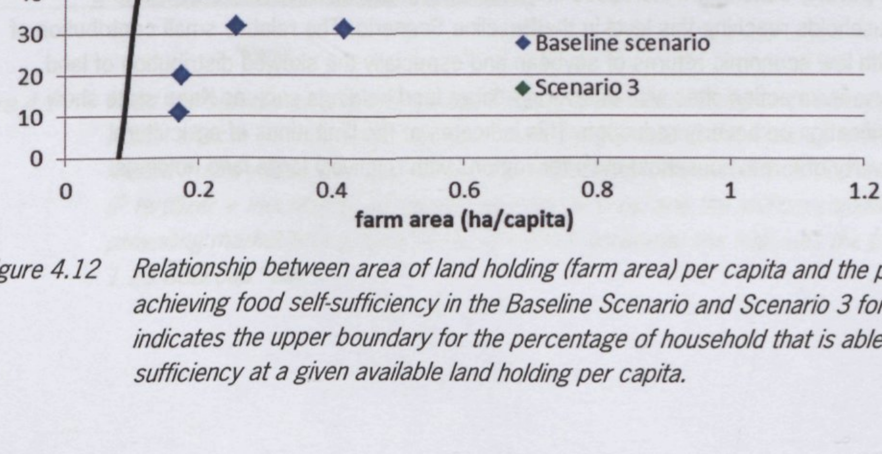


Figure 4.12 Relationship between area of land holding (farm area) per capita and the percentage of households achieving food self-sufficiency in the Baseline Scenario and Scenario 3 for the 29 action sites. The line indicates the upper boundary for the percentage of household that is able to reach food self-sufficiency at a given available land holding per capita.

Figure 4.13 provides the relationship between the area of land holdings (not harvested land) per capita and the percentage of households achieving the poverty benchmark of 1.25 USD cap^{-1} day^{-1} based on the results of Scenario 3 for the 29 action sites. The line in Figure 4.13 provides an upper boundary for the percentage of households in the action sites that is able to reach the poverty line as function of the land resources available per capita. Action sites below this upper limit may not be able to reach the maximum level because of differences in agro-ecological potential and economics (prices). In 11 action sites with less than 0.4 ha capita^{-1} available less than 50% of households is able to reach the poverty line of 1.25 USD cap^{-1} day^{-1} in the most intensive scenario.

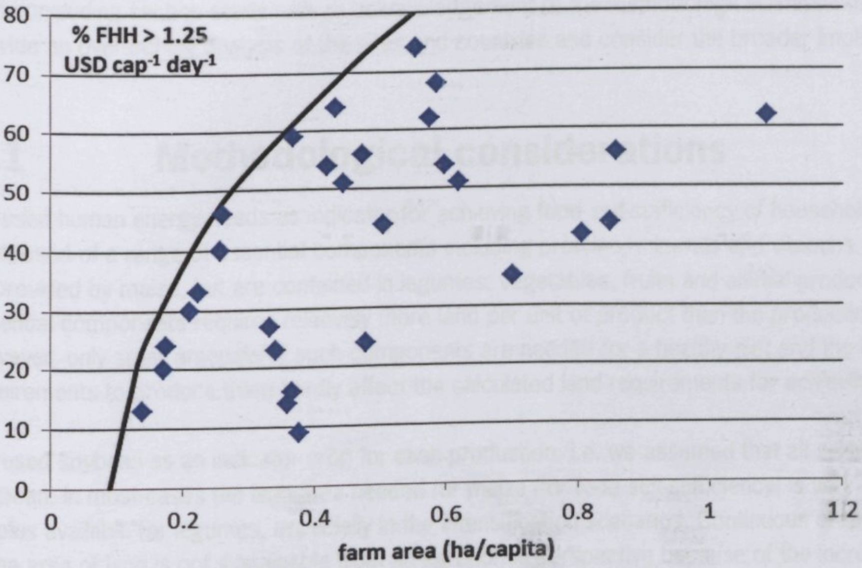


Figure 4.13 Relationship between land holding (farm area) per capita and the percentage of households achieving the poverty benchmark of 1.25 USD cap^{-1} day^{-1} based on the results of Scenario 3 for 29 action sites. The line indicates the upper boundary for the percentage of household that is able to reach 1.25 USD cap^{-1} day^{-1} at a given available land holding per capita.

5. Discussion and conclusions

Our results reveal the large differences in land endowments in relation to household size within and across the N2Africa action sites in sub-Saharan Africa (Giller *et al.*, 2011). Although we refer to these areas using the country names, these action sites cannot be taken to be representative of the countries as a whole. The N2Africa action sites were deliberately selected as locations where agricultural intensification using legumes showed promise - which means that the areas selected have good agroecological potential for the crops in terms of both climate and soils. This concluding section starts with an acknowledgement of the methodological limitations of our study. We then provide an overarching analysis of the sites and countries and consider the broader implications of our findings.

5.1 Methodological considerations

We used human energy needs as indicator for achieving food self-sufficiency of households while a healthy diet is composed of a range of essential components including proteins, minerals and vitamins. These components are not all provided by maize, but are contained in legumes, vegetables, fruits and animal products. Production of these essential components requires relatively more land per unit of product than the production of energy in maize. However, only small amounts of such components are needed for a healthy diet and the associated land requirements to produce them hardly affect the calculated land requirements for achieving food self-sufficiency.

We used soybean as an indicator crop for cash production, i.e. we assumed that all surplus land is cropped with soybean. In most cases the land area needed for maize (for food self-sufficiency) is very small in relation to the land surplus available for legumes, especially in the intensification scenarios. Continuous cropping of legumes on the same area of land is not sustainable from an agronomic perspective because of the increased risks for different types of pests and diseases. Also from a market perspective it may not be a wise choice for all farmers in a location to produce only soybeans. To arrive at sustainable crop rotations the surplus land needs to be cultivated with other crops than only soybean as assumed in the calculations. Because maize and other grain crops (e.g. sorghum and millet) are generally less profitable than soybean, other cash crops need to be identified that fit in such rotations. Such crops often exist within location-specific markets and agro-ecological contexts such as yam and cassava in Nigeria and groundnut and tobacco in Malawi and Zimbabwe, but are not feasible in all action sites. Hence, the assumption in our approach that all surplus land is being cropped by soybean merely implies that the associated gross returns can be considered as an upper boundary of expected financial benefits of cash crop production especially for action sites with few alternative cash crops.

Though the calculated land requirements are based on technically feasible production levels the estimated gross returns derived from maize and soybean production may be overestimated for two major reasons:

1. The estimated gross returns imply the returns to all labour needed in crop production. The estimated gross returns do not equal household income as most households would need to hire labour during labour-intensive field operations such as weeding and harvesting. This also highlights a further impediment for poorer farmers who tend to delay their own field operations to be able to earn money or food by working for wealthier farmers (Kamanga *et al.*, 2013). Especially in situations with large land surpluses, costs for hired labour will increase and thus may result in an overestimation of the gross returns.
2. We did not account for the costs associated with fertilizers and other inputs in maize production. Figure 5.1 provides some insight in the effect of accounting for nitrogen fertilizer costs on the value of maize production for food-self-sufficiency (expressed as gross return per capita per day). We assumed that nitrogen is applied in the form of urea and we used a retail price of 800 USD per ton based on national monthly urea prices (May-July 2013) from six of the eight countries available in the database of the International Fertilizer Development Center (IFDC). We illustrate the effect of incorporating N fertilizer costs in the gross return of the maize crop for food self-sufficient households in an action site of Mozambique in Figure 5.1 for the Baseline Scenario and Scenario 3 (i.e. 80% water limited maize yields). Because we do not know the exact amount of N fertilizer applied we show a range of fertilizer applications from 0 to 60 kg N ha^{-1} in the Baseline Scenario and up to

150 kg N ha^{-1} in Scenario 3. Maize yields in the latter scenario are much higher than in the Baseline Scenario and thus more fertilizers will be required to achieve these higher yields. The range of fertilizer rates used and the consequences for gross returns are a form of sensitivity analysis. Without accounting for N fertilizer costs the gross returns of maize for food self-sufficiency are the same in both scenarios as the same amount of maize per capita needs to be produced. When N fertilizer costs are accounted for, gross returns per capita per day decrease much faster in the Baseline Scenario than in Scenario 3 because of the larger share of fertilizer costs in the crop budget. It should be noted, however, that the gross returns associated with maize for food self-sufficiency form only a small part of the total gross income of households as shown in the different *scenarios (Figures 4.1 - 4.9). Figure 5.1 shows that the impact of disregarding N fertilizer costs in the* calculations is limited to maximum 0.07 USD per capita per day if 60 kg N ha^{-1} is applied in the Baseline Scenario and 0.04 USD per capita per day if 150 kg N ha^{-1} is applied in Scenario 3.

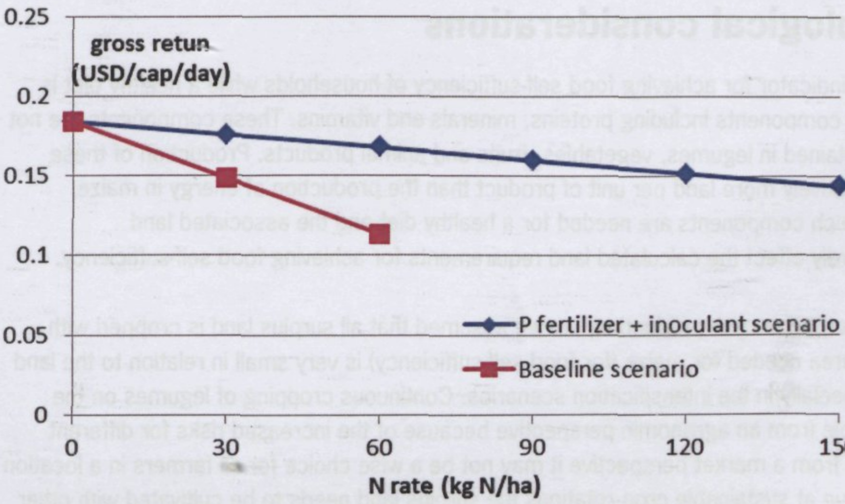


Figure 5.1 Effect of N fertilizer costs at different N rates for the gross return (in USD capita^{-1} day^{-1}) from maize production for food self-sufficient households in Mozambique (Sussudenga) in the Baseline Scenario and the P fertilizer + inoculant scenario (Scenario 3).

Related to the discussion on gross returns and important in relation to the uncertainty in household income is the role of other income generating activities of farm households such as income from livestock and off-farm employment (Table 3.1). Especially action sites with a large proportion of food insecure households in the Baseline Scenario, i.e. Rwanda (all sites), DRC (Kabare, Walungu), Malawi (Lilongwe), have few livestock and depend for a large share of their income on agriculture. In Rwanda, 90% of the households depend for 75% or more of their income on agriculture, and thus have little off-farm income. Wamaluma (Kenya) and Makoni (Zimbabwe), which both also score low on food self-sufficiency in the Baseline Scenario, have more livestock and also depend more for income on off-farm activities (Table 3.1).

Just as the availability of land resources differs across and within action sites also crop yields vary spatially associated with differences in soil fertility and management. Unfortunately, no reliable farmers' yield data was available from the survey. Actual maize yields could also have provided further insight into the performance of best farmers in the action sites, which could serve as a benchmark for other farmers and could have been used in one of the scenarios. Instead, simulated rainfed yields were used as an upper limit for maize production using a global crop modelling framework (Conijn *et al.*, 2011; Jing *et al.*, 2012). We used a conservative 80% of the water-limited production potential of maize as the upper yield limit. Recent application of the same framework in East Africa showed that simulated rain water use efficiencies compared favourably with the values found in the literature for maize, which provides some confidence in our results (Hengsdijk *et al.*, 2014). However, field measurements are needed to further validate the simulated yields of this framework for the different action sites.

5.2 Impact of agricultural intensification

At current maize and soybean yield levels (Baseline Scenario), many households in the DRC, Malawi, Rwanda and some action sites in Kenya and Zimbabwe are far from food self-sufficient. With current yields they face a land gap in terms of the land required for food self-sufficiency. The average land gap of households is in most countries less than 1 ha except for the DRC and Rwanda. In the Baseline Scenario, less than 50% of the households reached the poverty line of 1.25 USD capita^{-1} day^{-1} in all of the action sites. In most action sites of Malawi, Kenya, Rwanda and Mozambique even much less than 15% of the households reached this level of income. There are, however, remarkable differences within countries. For example, in Kenya Wamalumu stands out with only 1% of households reaching the poverty benchmark, compared with more than 14% in the three other Kenyan action sites. Also in Nigeria with overall relatively high gross returns per capita the differences across action sites are large, 42% of the households in Kano state reached the poverty benchmark, but only 16% in Northern Kaduna.

In Scenario 2, with a doubling of actual maize yields and improved soybean yields, food self-sufficiency for most households is within reach in many action sites, except in Rwanda and some sites in DRC and Zimbabwe. The production intensification, however, is insufficient for most households to benefit from market-based development as only in three sites (Guruve in Zimbabwe, Kano State in Nigeria and Upper West region in Ghana) more than 50% of the households is able to earn 1.25 USD capita^{-1} day^{-1} or more.

Food self-sufficiency can be achieved by most households in Scenario 3, but the percentage of households that earn more than 1.25 USD cap^{-1} day^{-1} remains limited: In 12 out of the 29 action sites 50% (or more) of the households reach this poverty line, in the other 17 action sites (often much) less than 50% of the household achieve this level. Malawi and Rwanda are clearly the worst cases, even with a doubling in the price of soybean only 40 to 64% of the households is able to earn 1.25 USD cap^{-1} day^{-1} or more. Zimbabwe, Nigeria and Ghana are the best performing countries, with a doubling of the soybean prices even more than 80% of the households is able to reach 1.25 USD cap^{-1} day^{-1}.

Although this is a coarse-grained analysis, the scenarios indicate the potential and the boundaries within which agricultural intensification can assist rural households to achieve food self-sufficiency on the one hand, and of the potential benefits of smallholders in market-based developments and associated effects on reducing rural poverty on the other hand. With respect to achieving food self-sufficiency, a doubling of the actual maize yields is sufficient to satisfy household food needs, except for Rwanda and two sites in the DRC. The most 'intensive' Scenario 3 assumes good maize yields (80% of simulated water-limited yields) and good soybean yields as determined in demonstration and well-managed dissemination trails in or near the action sites. These yields are much greater than those achieved with farmers' current practices and would require strong investments in knowledge, infrastructure and human capacity. While these production levels allow land gaps to close and free land for commercial production, impacts on reducing poverty as measured by the number of households earning more than 1.25 USD capita^{-1} day^{-1} remain moderate. Our results, however, also suggest hotspots where farmers may be more able to join market-based developments such as in different action sites in Nigeria related to more favourable land endowments.

5.3 Rural Worlds

Seville *et al.* (2011) and Vorley *et al.* (2012) provided a stylized classification of smallholders participating in different markets and they identify a number of interventions to involve smallholders in more remunerative markets (Figure 5.2). According to this classification up to 80% of the smallholders are currently not or hardly connected to markets, 15% of the smallholders better connected to markets and a small fraction are commercial farmers.

Our analyses allows us to divide smallholders into farm households into those that are: (i) not food self-sufficient; (ii) food self-sufficient but earn less than 1.25 USD cap^{-1} day^{-1} and (iii) food self-sufficient and earn more than 1.25 USD cap^{-1} day^{-1}. The first cluster is formed by the extreme poor, which are net food consumers and need income from off-farm activities for survival. The second cluster consists of poor households, which occasionally can sell to markets but not sufficiently to escape poverty. The last cluster of households has better opportunities to get involved in markets and to earn more with agriculture than the poverty benchmark. In this section we characterize these farm household clusters in terms of (the variation in) available land resources and income (gross return cap^{-1} day^{-1}) for the Baseline Scenario and Scenario 3 to explore the potentials of agricultural intensification to help farmers to 'step up' (Figure 5.2).

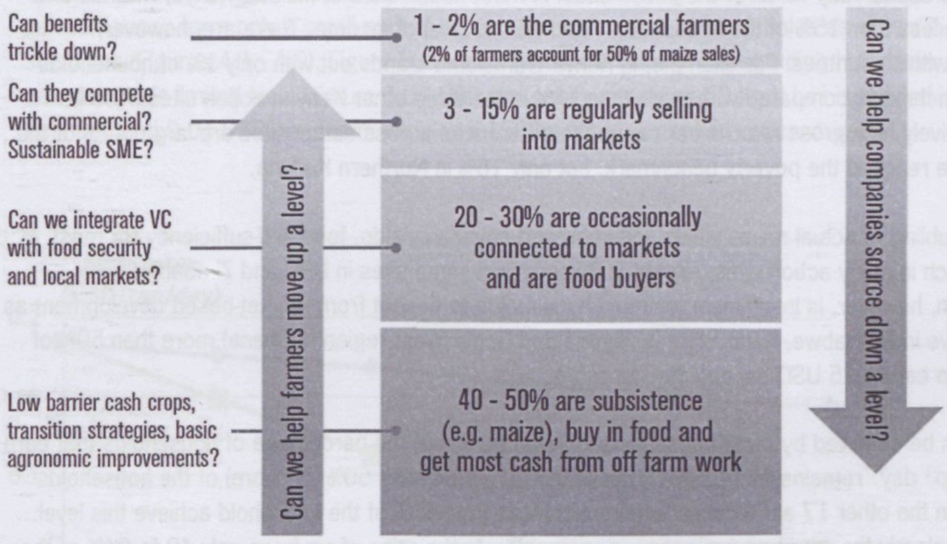


Figure 5.2 *Stylized classification of smallholders in different markets and interventions to involve smallholders in more remunerative markets (from Seville et al., 2011).*

Figure 5.3a shows the population size of the three clusters of farm households, and the average gross returns and land endowments of each cluster in the Baseline Scenario. The largest cluster consists of poor farm households (51%) followed by the extreme poor (29%) and the rest of the farmers is food self-sufficient and earns more than 1.25 USD cap^{-1} day^{-1} with agriculture (20%). The extreme poor have on average 0.9 ha (harvested area) available per household, the poor households 2.4 ha and the better off households 7.5 ha. The variation in land endowments within each cluster of farmers is shown in Figure 5.3b. The average gross returns in the cluster with extreme poor households are 0.16 USD cap^{-1} day^{-1}, 1.17 USD cap^{-1} day^{-1} for the poor households, and 2.43 USD cap^{-1} day^{-1} for the better off. The variation in earnings within each cluster is shown in Figure 5.3c.

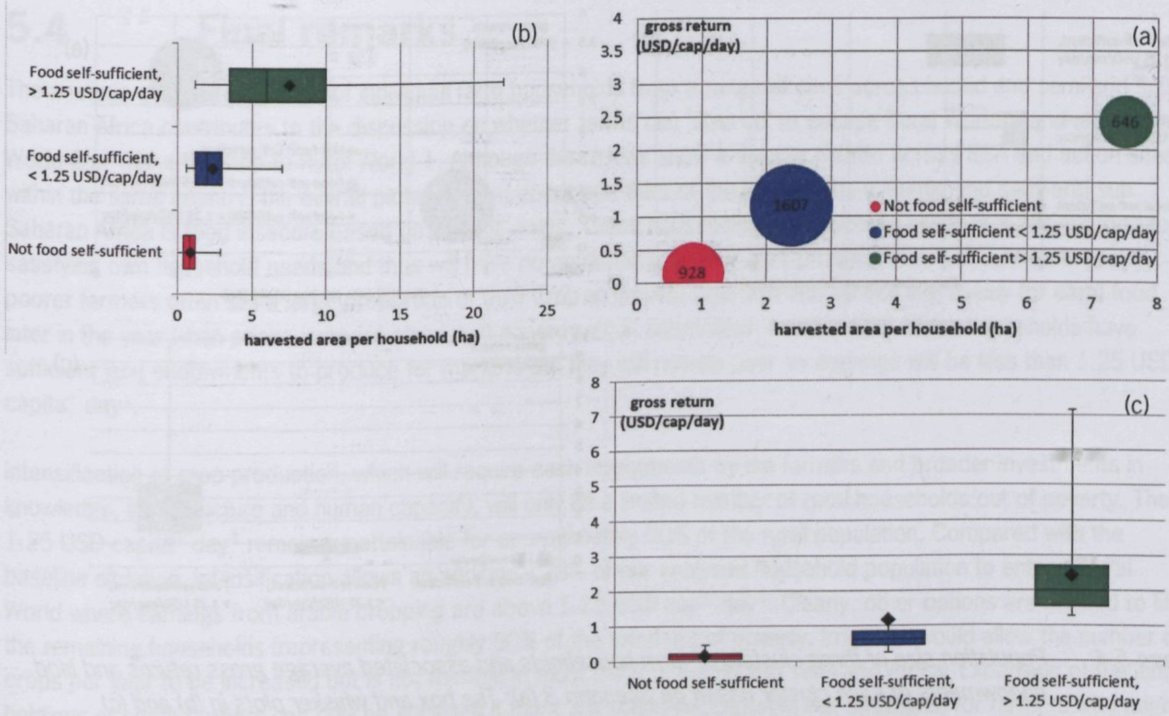


Figure 5.3 *Population size of three clusters of farm households and associated average gross returns and land endowments of each cluster using the Baseline Scenario (a). The box and whisker plots in (b) and (c) characterize the variation in land endowments and gross returns, respectively, for the three clusters. The boxes indicate the range from the first to third quartile, the solid line within the boxes is the median, whiskers indicate the 2nd and 98th percentile, and the diamond the average.*

Agricultural intensification as realized by Scenario 3 results in a shift of farmers to different Rural Worlds as shown in Figure 5.4a. The largest group consists still of poor farm households (food self-sufficient but earning less than 1.25 USD cap^{-1} day^{-1}) and hardly changes in size (48%). Especially the size of the extreme poor households is reduced to only 4% of the total population, and the proportion of better off farmers increased considerably to 48% of the population. As a consequence of the transition of relative small farm households to other Rural Worlds the average land endowment per cluster decreases compared to the Baseline Scenario. In Figure 5.4a this implies a shift of the bubbles to the left compared to the bubbles in Figure 5.3a. Extremely poor households in Scenario 3 have only 0.1 ha, the poor households 1.4 ha and the better off farm households 4.8 ha. The average gross returns per cluster decrease for the extreme poor and poor households with 20-30% to 0.13 and 0.74 USD cap^{-1} day^{-1}, respectively. The average gross returns of the better off farm households increase with the same percentage to 3.04 USD cap^{-1} day^{-1}. The variation in land endowments and earnings within each cluster in this scenario is shown in Figures 5.3b and 5.3c, respectively.

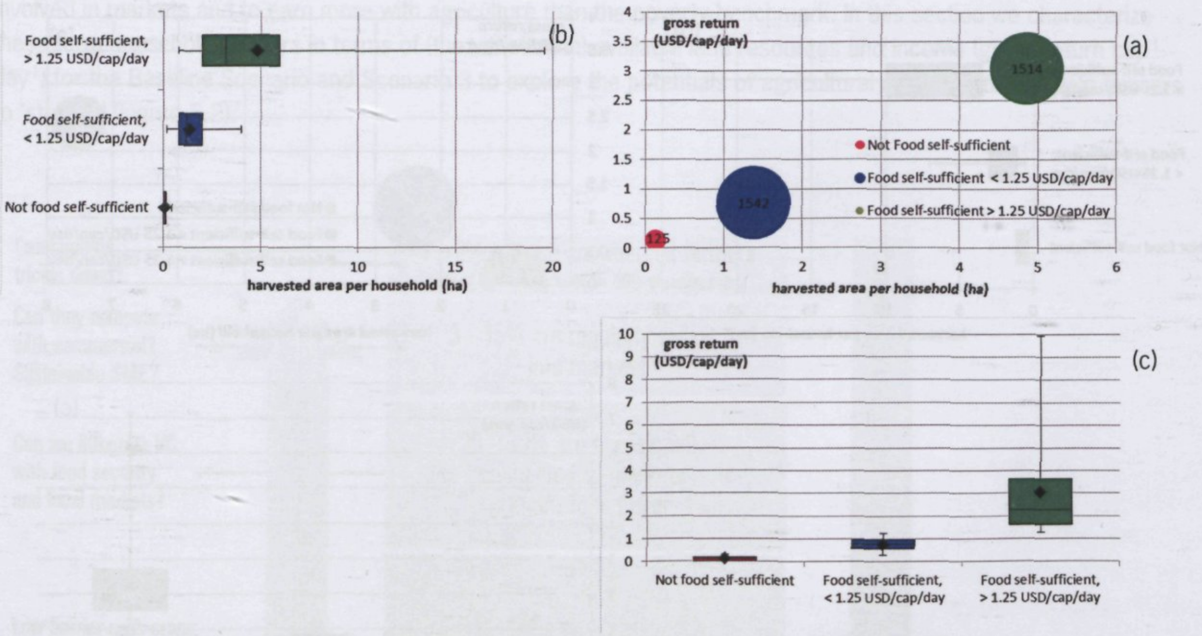


Figure 5.4 Population size of three clusters of farm households and associated average gross returns and land endowments of each cluster based on Scenario 3 (a); The box and whisker plots in (b) and (c) characterize the variation in land endowments and gross returns, respectively, for the three clusters. The boxes indicate the range from the first to third quartile, the solid line within the boxes is the median, whiskers indicate the 2nd and 98th percentile, and the diamond the average.

Figure 5.5 shows the relationship of the land availability per capita with the land gaps and gross returns for the entire population of farm households in the Baseline Scenario. When land availability per capita drops below 0.1 ha farm households are not able to satisfy food self-sufficiency as all farm households have a land gap. Even below 0.2 ha per capita most households have a land gap, though smaller. Farm households with more than 0.2 ha per capita are increasingly able to satisfy own food requirements, while with more than 0.3 ha of land available per capita most households are food self-sufficient. Households with approximately 0.6 ha per capita or more start to earn more than 1.25 USD cap^{-1} day^{-1}. However, only with around 1.5 ha per capita most farm households are able to earn more than the poverty benchmark. Income increases further linearly, because costs for hired labour to cultivate surplus land are not taken into account. Although differences occur across sites as indicated by the diverging range of land gaps and gross returns for a given land endowment both relationships in Figure 5.5 provide general thresholds to differentiate between various Rural Worlds.

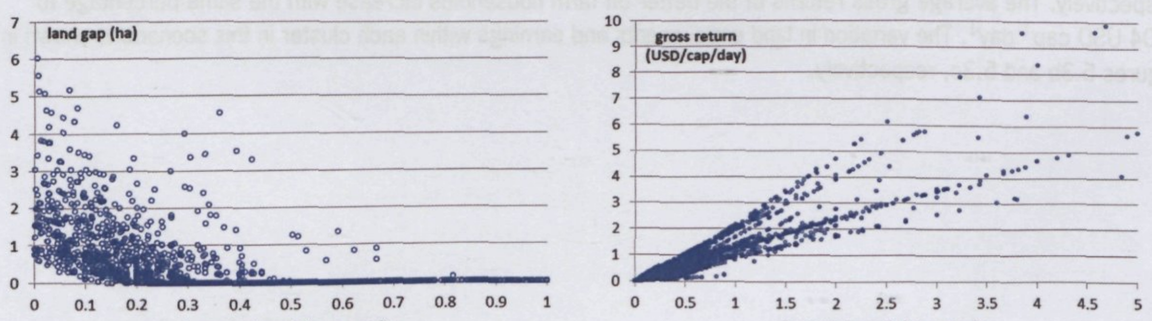


Figure 5.5 Relationship of the land availability with the land gap per household (left) and gross returns (right) for the entire population of farm households in the Baseline Scenario. For reasons of clarity only harvested area data (X-axis) is shown up to 1 ha per capita (left) and 5 ha per capita (right).

5.4 Final remarks

The analysis of a large data set of individual farm households from a range of sites across humid and semi-arid sub-Saharan Africa contributes to the discussion on whether farms can 'step up' to escape Rural World 3 and enter Rural World 2 or make the step to Rural World 1. Although the results show a diverse palette across SSA and action sites within the same country, the overall picture is that about one third of the households in humid and semi-arid sub Saharan Africa is food insecure based on current yields. These households are unable to produce sufficient food for satisfying own household needs and thus will have no marketable surplus if all produce were consumed. In reality, poorer farmers often sell a large proportion of their crop at harvest time and end up needing to buy (or earn) food later in the year when prices increase strongly (Leonardo *et al.* submitted). Another 50% of the households have sufficient land endowments to produce for markets but they will remain poor as earnings will be less than 1.25 USD $capita^{-1}$ day^{-1}.

Intensification of crop production, which will require cash investments by the farmers and broader investments in knowledge, infrastructure and human capacity, will only lift a limited number of rural households out of poverty. The 1.25 USD $capita^{-1}$ day^{-1} remains unattainable for approximately 50% of the rural population. Compared with the baseline situation, intensification allows an additional 28% of our analysed household population to enter a Rural World where earnings from arable cropping are above 1.25 USD cap^{-1} day^{-1}. Clearly, other options are needed to lift the remaining households (representing roughly 50% of the total) out of poverty. Irrigation would allow the number of crops per year to be increased but is not feasible in most parts of humid and semi-arid Africa. Expansion of the land holdings of some farmers can only be achieved if there are socially-acceptable exit strategies for farmers who might be prepared to leave rural areas. Our findings strongly support the view that agriculture alone cannot lift the majority of the rural poor out of poverty in Africa. Agricultural development needs to proceed hand-in-hand with development of off-farm employment opportunities as a prerequisite to facilitate transition to a more equitable future.

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Appendix I.
Farm household questionnaire

N2Africa Baseline Survey - Farm households (Rapid farming system characterisation)

Date of interview: ____/_____/2010 Country: ________________
Enumerator: ______________________
Action site (District/Secteur/Cell): ________________
Location/village: ___________________
Homestead Coordinates: Northing: ______ Easting:____ Altitude: _____

Checked by: ________________
Date checked:________________
Data entry by: ________________

Starting time: __________

- Introduction

Introduce yourself and the N2Africa project (see separate sheet). Explain the purpose of the survey and assure the interviewee of the confidentiality. Make sure to check if the farmer has any questions at this time.

- A. Demographic information

A.1. Name of respondent: ______________________________
A.2. Household head: Yes / No
A.3. Total number of people in household: ____________
A.3. Is anyone in your household affiliated to a (community) organisation? Yes/ No

If yes, please fill the table below:

Name of the organisation	Purpose/objective	Who in household is a member?	Member since
1			
2			
3			
4			
5			

A.4. Household composition and employment:

No.	Name	Age	Gender	Schooling level (completed)	Involved in on-farm activities			Involved in off-farm income generation		
			1) Male 2) Female	1) Primary 2) Secondary 3) Post-secondary[1] 4) University, 5) Informal education/other 6) None	1) Yes, full-time	2) Yes, but only seasonal	3) No, not at all	1) Yes 2) No	If yes, what kind of income generating activity/ies? *(See below this table)*	Earnings? (in money and/or food or other goods) *(indicate the period, for example per week, per month, etc.)*
1										
2										
3										
4										
5										
6										
7										
8										
9										
10										
11										
12										
13										
14										
15										

1) sale of firewood or timber, 2) sale of charcoal, 3) remittances, 4) trading, 5) handiwork (e.g. tailoring), 6) rent, 7) work on other people's fields (ganyu), 8) food for work, 9) pension, 10) sale of bricks, 11) fish, 12) own business, 13) other ...

[1] For example vocational training.

- B. Income

B.1. What do **<u>you</u>** consider to be the most important source of household income:

1) Cropping ____ 2) Livestock ____ 3) (Petty) trade _____
4) Off-farm income ____ 5) Remittances _____ 6) Other (specify) ______

B.2. Can you estimate the portion of the income in your household coming from farming activities and the portion from off-farm sources? Choose what best describes your situation:

	Tick
1) All income from farming	
2) Most from farming, a small part from off-farm sources	
3) About half-half from farming and off-farm	
4) More from off-farm sources and less from farming	
5) No Income from farming, all from off-farm sources	

[Note: it is not about the <u>amount</u> of money, but estimated proportions, for example half-half, or a quarter of the income is generated off-farm, the rest is from farming activities.]

- C. Labour

Do you hire labour for your farm or work in the fields? 1) Yes ___ 2) No ___
If yes, indicate for what kind of activities:

Activity	1) Yes 2) No	Mainly for which crop(s)?	How long (no. of days) & how many people hired?	Cost (money and/or food) (indicate per year, per month or per day)
Land preparation				
Planting				
Weeding				
Harvesting				
Transport harvest home				
Processing				
Other				

- D. Household assets/resources (Wealth indicators)

		Tick if yes	**Number of items** *(if relevant)*
1	**House: walls**		
a	Bricks (burnt)		
b	Un-burnt bricks or mud bricks		
c	Poles (bamboo or other), planks		
d	Other (specify):		
2	**House: roof**		
a	Grass, thatch		
b	Iron sheets, asbestos, tin		
c	Tiles		
d	Other (specify):		
3	**House: flooring**		
a	Mud		
b	Concrete, cement		
c	Tiles		
d	Other (specify):		
4	**Transport**		
a	Bicycle (if yes, total no. in HH)		
b	Motorbike		
c	Car or pick-up		
d	Truck		
e	Other (specify):		
5	**Communication & other equipment**		
a	Cell phone (if yes, total no. in HH)		
b	Radio		
c	Television		
d	Fridge		
e	Other (specify):		
6	**Power**		
a	Solar power		
b	Car battery		
c	Electricity		
d	Paraffin		
e	Generator		
d	Other (specify):		
7	**Cooking**		
a	Wood		
b	Charcoal		
c	Paraffin		
e	Other (specify):		

		Tick if yes	Number of items *(if relevant)*
8	**Tools for land preparation**		
a	Hoe		
b	Panga/ cutting knife		
c	Watering cans		
d	Plough		
e	Tobacco drying shed		
f	Tobacco pressing machine		
g	Wheel barrow		
h	Ox cart, donkey cart		
i	Tractor		
j	Others (specify):		
9	**Facilities for livestock**		
a	Roofed shelter		
b	Pen, kraal, fenced place		
10	**Storage of harvest**		
a	Bags		
b	Mud silo, granary		
c	Earthenware pot		
d	Other (specify):		
11	**Source of water (domestic use, drinking water)**		
a	Private well		
b	Private borehole		
c	Community well		
d	Community borehole		
e	Tap (piped water)		
f	Surface water (river, stream, etc)		
g	Others (specify):		
12	**Irrigation**		
a	Treadle pump		
b	Diesel pump		
c	Other (specify):		
13	**Other:** ***[Here you can note what a farmer wants to add and/or could not fit above]***		

- E. Livestock ownership

	Number				
	Owned	**Cared for**	**Total**		**Number**
Cattle (total no.)				Chickens	
Cows for dairy				Guinea fowls	
Oxen				Turkeys	
Sheep				Guinea pigs	
Goats				Rabbits	
Donkeys				Doves/pigeons	
Pigs				Bees	
Horse				Fish (fish ponds?)	
				Other (specify)	

- F. Land holding

Where possible, fields of farmers will be measured. In some cases this can be done for example by sending a team of two enumerators; one to interview the farmer, the other one to go around the fields to measure the plots. In other cases, the enumerator will do both the interview and the measurements. Country team are to determine the appropriate way to do this.

No. of field	Acreage (ha, acres, m x m)	1) Own field 2) Rented field 3) Rented out 4) Borrowed from someone 5) Lend to someone else	If rented, how much is payment in money and/or produce?	How long have you been farming/ using this field?	Use: 1) crops 2) fallow 3) pasture 4) woodlot 5) other	Main crops grown in the last season	Who controls the use of land? 1) husband 2) wife 3) both 4) owner 5) other	Who controls the harvest from this field? 1) husband 2) wife 3) both 4) owner 5) other
1								
2								
3								
4								
5								
6								
7								
8								
9								
10								
11								
Total no.:								

- G. Production activities: Legumes

G.1. Have you cultivated legumes in the past 5 years? 1) Yes ___ 2) No ___

G.2. Which legumes did you cultivate last season:

Legume type	Variety	Area	Inputs used on legumes and amounts			
			Mineral fertilizer(s), what kind?	Organic fertilizer(s), what kind?	Inoculant	Other (specify):
Cowpeas						
Soybeans						
Common beans/ Bush beans						
Climbing beans						
Bush beans						
Groundnuts						
Other:						
Other:						
Fodder legume						
Total land allocated to grain legumes:						
Total land allocated to fodder legumes:						
Total land allocated to legumes:						

G.3. Total production of legumes:

	Legume	Total production last season[2]	Amount kept for household	Amount to keep for seed, paying labour, etc.	Amount for sale	Who makes decision on division of harvest? 1) Wife 2) Husband 3) Both? 4) Other (specify)
1						
2						
3						
4						
5						
6						

G.4. For your agricultural production other than legumes, what inputs do you obtain?

	Crop	Seeds / planting material purchased? 1) yes 2) no	Mineral fertilizer What kind?	Organic fertilizer What kind?	Biocides/ pesticides	Other inputs (specify)
1						
2						
3						
4						
5						
6						
7						

2 Local units like baskets, buckets, scotch carts, different sizes of bags, etc all need to be converted to kilogrammes

G.5. Production and utilisation of your **major crops**, apart from legumes:

	Crop	Total production last season	Amount kept for household	Amount to keep for seed, paying labour, etc.	Amount for sale	Who makes decision regarding the division? 1) Wife 2) Husband 3) Both 4) Other (specify)
1						
2						
3						
4						
5						
6						
7						

H. Nutrition & Legume utilisation

H.1. What are the most important foods for your household?

1.	4.
2.	5.
3.	6.

H.2. In your household, how many meals do you take per day? *Here we refer to 'real' meals, not snacks and/or drinks.*

1) Once per day ____ 2) Twice per day _____ 3) Three times per day ______

H.3. How often do you eat grain legumes in your household? (Which kinds, number of times per week, main dish or side dish)

	Which grain legume	Frequency per week		How eaten? Main dish or side dish?
		Peak season	Low season	
1				
2				
3				
4				
5				

H.4. Do you use legume hauls for anything? (E.g. as feed for own livestock, sale to other people, burning, etc.)

	Type of legume	Hauls used for which purpose
1		
2		
3		
4		
5		

I. Markets

	Place and/or name[3]	Kind of market (local, regional, etc.)	Frequency of market (once a week, every day, etc.)	Distance (for example, kilometres or time walking)	Means of transport	Cost of transport to market (1 person, 1 way)	Do you use it for 1) sale, 2) purchase 3) both	Main products at market 1) household goods 2) clothes 3) agricultural produce 4) inputs 5) livestock 6) other (specify)
1								
2								
3								
4								
5								

[3] If possible, take the GPS coordinates of the places concerned, for example when you are passing through on your way.

Sketch of the farm layout (simple overview of homestead, indicate (main) fields and if appropriate, other relevant features such as well, orchard, etc.):

OPTIONAL
Sometimes, a sketch may help to understand the lay-out of the farm, all the fields and other possible features. Make sure the farmer is still up to this!

Please, thank the respondent for her/his time.
Check if the farmer has any questions at this time.

Ending time: ________

Appendix II.
Yield and price data

Table I. *Yield data used in the food self-sufficiency and land gap calculations, see Section 2.4 for sources of yield data. Actual maize and soybean yields are used in the Baseline Scenario, improved soybean and twice the actual maize yields in Scenario 2, and the attainable soy bean combined with 80% water - limited maize yields in Scenario 3.*

	Country	Action site	Latitude action side	Longitude action side	Actual maize yield (kg ha^{-1})	80% water-limited maize yield (kg ha^{-1})	Actual soybean yield (kg ha^{-1})	Improved soybean yield (kg ha^{-1})	Attainable soybean yield (kg ha^{-1})
1	DRC	Kalehe	-2.2083	28.875	798	5296	1100	1200	1880
2	DRC	Kabare	-2.3750	28.7917	798	5296	1100	1200	1880
3	DRC	Walungu	-2.70830	28.625	798	5560	1100	1200	1880
4	Ghana	Northern region	10.8750	-1.0417	1138	4392	1160	1340	1470
5	Ghana	Upper East region	10.1250	0.2917	1269	4795	1160	1340	1470
6	Ghana	Upper West region	10.1140	-2.4366	1007	4623	1160	1340	1470
7	Kenya	Wamalumu	0.1250	34.7083	1631	8480	570	930	1180
8	Kenya	South Gem	-0.0417	34.4583	1631	5211	570	930	1180
9	Kenya	Bondo	-0.1250	34.2917	1631	5211	570	930	1180
10	Kenya	Kanyamkago	-1.0417	34.4583	1273	4512	570	930	1180
11	Malawi	Lilongwe	-13.9833	33.7833	1240	9389	840	1200	1420
12	Malawi	Dowa	-13.6873	33.9285	1466	8136	840	1200	1420
13	Malawi	Salima	-13.7807	34.4585	1466	5121	840	1200	1420
14	Malawi	Ntcheu	-14.8556	34.6440	1240	8788	840	1200	1420
15	Mozambique	Mandimba	-14.3533	35.6417	1046	4658	840	1200	1640
16	Mozambique	Gurue	-15.4667	36.9833	759	5216	840	1200	1640
17	Mozambique	Sussundenga	-19.4129	33.2954	1284	5647	840	1200	1640
18	Nigeria	Kano state	11.6948	8.5387	1032	6274	750	1150	1420
19	Nigeria	Northern Kaduna	10.8060	7.7152	1447	3805	750	1150	1420
20	Nigeria	Southern Kaduna	9.7791	8.31258	1447	4278	750	1150	1420
21	Rwanda	Musambira	-2.0382	29.9100	368	7218	1100	1200	1880
22	Rwanda	Musenyi	-2.2095	30.0612	633	6374	1100	1200	1880
23	Rwanda	Rukara	-1.8422	30.4962	633	6762	1100	1200	1880
24	Rwanda	Burera	-1.4458	29.7368	1036	4855	1100	1200	1880
25	Rwanda	Gakenke	-1.5966	29.8806	1036	5313	1100	1200	1880
26	Zimbabwe	Guruve	-16.6609	30.7034	1682	9844	1436	1976	2293
27	Zimbabwe	Makoni	-18.5360	32.2218	638	10561	1436	1976	2293
28	Zimbabwe	Mhondoro	-18.2188	30.1378	2413	9276	1436	1976	2293
29	Zimbabwe	Mudzi	-16.7956	32.5375	1775	4116	1436	1976	2293

Table II. Price data used in the land gap calculations, see Section 2.4 for sources of yield data. P fertilizer and inoculum costs refer to soybean and have been used in Scenarios 2 and 3.

	Country	Action site	Price soybean (USD/kg)	Price maize (USD/kg)	P fertilizer costs (USD/ha)	Inoculum costs (USD/ha)
1	DRC	Kalehe	0.80	0.40	150	5.50
2	DRC	Kabare	0.80	0.40	150	5.50
3	DRC	Walungu	0.80	0.40	150	5.50
4	Ghana	Northern region	0.89	0.22	90	5.00
5	Ghana	Upper East region	0.89	0.22	90	5.00
6	Ghana	Upper West region	0.89	0.22	90	5.00
7	Kenya	Wamalumu	0.61	0.34	194	5.50
8	Kenya	South Gem	0.61	0.34	194	5.50
9	Kenya	Bondo	0.61	0.34	194	5.50
10	Kenya	Kanyamkago	0.61	0.34	194	5.50
11	Malawi	Lilongwe	0.55	0.33	225	5.00
12	Malawi	Dowa	0.55	0.33	225	5.00
13	Malawi	Salima	0.55	0.33	225	5.00
14	Malawi	Ntcheu	0.55	0.33	225	5.00
15	Mozambique	Mandimba	0.54	0.21	144	5.00
16	Mozambique	Gurue	0.54	0.21	144	5.00
17	Mozambique	Sussundenga	0.54	0.21	144	5.00
18	Nigeria	Kano state	0.60	0.59	126	5.00
19	Nigeria	Northern Kaduna	0.60	0.59	126	5.00
20	Nigeria	Southern Kaduna	0.60	0.59	126	5.00
21	Rwanda	Musambira	0.62	0.23	102	5.50
22	Rwanda	Musenyi	0.62	0.23	102	5.50
23	Rwanda	Rukara	0.62	0.23	102	5.50
24	Rwanda	Burera	0.62	0.23	102	5.50
25	Rwanda	Gakenke	0.62	0.23	102	5.50
26	Zimbabwe	Guruve	0.55	0.33	86	5.00
27	Zimbabwe	Makoni	0.55	0.33	86	5.00
28	Zimbabwe	Mhondoro	0.55	0.33	86	5.00
29	Zimbabwe	Mudzi	0.55	0.33	86	5.00