What role for legumes in sustainable intensification? – case studies in Western Kenya and Northern Ghana for PROIntensAfrica

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N2Africa

Putting nitrogen fixation to work for smallholder farmers in Africa

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Summary

N2Africa was selected as a case study within the PROIntensAfrica initiative. In this case study, N2Africa focused on the potential role of legumes in sustainable intensification. The case study was conducted in two of the N2Africa countries, Ghana and Kenya, and involved literature research, stakeholder interviews, a household survey and a final stakeholder workshop. The objectives of the case study were to identify drivers of change, the current role of legumes as pathway for sustainable intensification and priority areas for research for smallholder farming systems in western Kenya and northern Ghana. A set of principles, criteria and indicators to assess sustainability of farming systems was selected based on N2Africa's objectives and additional literature study.

Important drivers of change in both Ghana and Kenya were population pressure, poor government policies and external development projects and agencies. Specific for Kenya were changing market conditions and yield reducing factors in legumes, and for Ghana improved availability of inputs, climate change and improved education.

The role of legumes in sustainability of farming systems at household level was presented in spider charts with scores on a scale from 0-10 for principles and indicators. Average scores on the level of principles were below 6 for nearly all principles in both case study countries, meaning that sustainability of interviewed households could be considered low or just sufficient. Outcomes on the level of principles were very similar between countries and between research sites within a country. Compared with Ghana, Western Kenya had smaller yield gaps for maize and legumes. In contrast, the score for protein from legumes in Northern Ghana was almost double that of Western Kenya. Scores for N input from N_2-fixation, N surplus and nitrogen use efficiency on farm level were low in both countries. There were no consistent differences between farms with a small and large share of their farm under legumes (legume intensity), although yield gaps of legumes and in particular maize were more positive for households with a higher legume intensity in Western Kenya, and households with a higher legume intensity had higher indicator scores for farm size, nitrogen use efficiency, and market access in Northern Ghana. Although some general patterns could be found, there was a lot of variation in individual households' results per indicator. Assessing the reasons for high and low scores of an indicator should lead to the identification of entry points for enhancing sustainability.

Priority areas for research identified in both Western Kenya and Northern Ghana were the effects of population pressure and reduced interest of youth in farming on agricultural production; the availability of knowledge for farmers and the facilitation of farmers in well informed decision making; the need for labour saving technologies and mechanisation in soyabean and groundnut (harvesting and threshing) and crop-livestock integration. In Kenya, additional priorities were the assessment of the economic viability of legumes and the role of the government to institutionalize legume cultivation. Additional priorities in Northern Ghana were increased availability and affordability of legume inputs; identification of options for value addition through small or medium scale processing enterprises; identification of optimal intercropping configurations for cereal-legume intercropping systems; climate resilient cropping practises and area specific fertiliser recommendations.

The need for integrated options were key in both case study countries and exemplified the need for embedding pathways for sustainable intensification, such as the use of legumes, at all system levels. The wide variation in the indicators for sustainability among households once more emphasized that such integrated solutions should consider the enormous diversity that exists in smallholder farming systems in SSA.

1 Introduction

N2Africa 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 (www.n2africa.org). The project’s vision of success is to build sustainable, long-term partnerships to enable African smallholder farmers to benefit from symbiotic N_2-fixation by grain legumes through effective production technologies, including inoculants and fertilizers. With funding from the Bill & Melinda Gates Foundation, N2Africa began a second phase on the 1st of January 2014. The project will run for five years and is led by Wageningen University (WUR) together with the International Institute of Tropical Agriculture (IITA) and the International Livestock Research Institute (ILRI). The project works through many partners in Ghana, Nigeria, Ethiopia, Tanzania and Uganda (Core countries), and in DR Congo, Rwanda, Kenya, Mozambique, Malawi and Zimbabwe (Tier 1 countries).

N2Africa was selected as a case study within the PROIntensAfrica initiative (www.intensafrica.org). PROIntensAfrica aims to build a long-term research and innovation partnership between Africa and the European Union, focusing on the improvement of food and nutrition security through sustainable intensification. N2Africa as case study focuses on the potential role of legumes in sustainable intensification. The case study was conducted in two of the N2Africa countries, Ghana and Kenya, and involved literature research, stakeholder interviews and a household survey. An important part of the case study also involved the discussion and verification of the results with a range of stakeholders during workshops in Ghana and Kenya.

The following objectives were identified for this case study:

- To describe drivers of change that have influenced smallholder farming systems in northern Ghana and western Kenya
- To describe the current role of legumes as pathway for sustainable intensification for smallholder households in western Kenya and northern Ghana
- To identify priority areas for research around the question ‘What role for legumes as pathway for sustainable intensification of farming systems in western Kenya and northern Ghana?’

In the following chapter the context of N2Africa and sustainability assessment of farming systems is discussed. This is followed by the methodology of this case study. In Chapter 4 the results on drivers of change in the case study areas are presented, followed by the results of the study on the current role of legumes as pathway for sustainable intensification in Chapter 5. Chapter 6 describes the priority areas for research that were identified, which is followed by some concluding remarks in Chapter 7.

2 Background

2.1 Legumes as pathway for sustainable intensification

The main objective of sustainable intensification is to produce more outputs whilst using less inputs per unit output (The Montpellier Panel 2013). This key focus on resource use efficiency, among other reasons, makes sustainable intensification a contested concept (Kuyper and Struik 2014; Godfray 2015). Loos et al. (2014) for instance pointed at the lack of equitable distribution of food (food security) and individual empowerment of different members of society in current studies around sustainable intensification. Tittonell (2014) put forward the need for integrating ecological principles using the concept of ecological intensification instead of sustainable intensification. The Sustainable Development Solutions Network (SDSN) however, summarized their objective for sustainable intensification much more broadly than resource use efficiency alone:
"*To provide sufficient, accessible, nutritious food, while enabling economic and social development in rural areas and treating people, animals and the environment with respect.*" (SDSN 2013, p. 16)
Grain legumes can fulfil part of these objectives of sustainable intensification and are therefore seen as an important pathway for sustainable intensification in SSA (Vanlauwe et al. 2014). They not only fix additional N inputs that can improve long term soil fertility, they also produce nutritious grains which often have a high market value (Giller et al. 2013). N2Africa aims to optimize the benefits of the agro-ecological process of symbiotic N_2-fixation and to improve legume yields using the formula:

$$(G_L \times G_R) \times E \times M$$

Where G_L stands for the genotype of the legume, G_r stands for the genotype of the rhizobium strain, E stands for environment, and M stands for management. N2Africa results show that environmental conditions (e.g. poor soils, drought) and poor management (no P-based fertiliser, late sowing, low planting densities) often override the potential of good legume and rhizobium genotypes in smallholder farming systems (www.N2Africa.org). Legume technologies therefore need to be tailored to fit within the diverse smallholder farming systems of sub-Saharan Africa to be a viable pathway for sustainable intensification.

2.2 Assessing sustainability of farming systems

With sustainable intensification being a debated concept, Struik et al. (2014) point at the need for justifying and being clear about the reasoning on which aspects of sustainable intensification one takes into account when using the concept of sustainable intensification. By explaining the decision-making process on which aspects or indicators of sustainability are taken into account for preforming a sustainability basement, others can take note of assumptions, norms and values that lie behind it and eventually take part in the discussion (Struik et al. 2014). A hierarchical approach of principles, criteria and indicators helps to structure and clarify indicator selection in such an assessment (Van Cauwenbergh et al. 2007; Florin et al. 2012). In this, "Principles are overarching ('universal') attributes of a system. Criteria are the rules that govern judgement on outcomes from the system and indicators are variables that assess or measure compliance with criteria." (Florin et al. 2012). Fig. 1 gives an example on how the reasoning for choosing an indicator belonging to a criterion can be clarified by indicating what the (assumed) driver is which is linking this criteria and its indicator. Showing this causal relationship not only opens the debate on which indicators are identified, it also helps to identify meaningful indicators (Niemeijer and de Groot 2008).

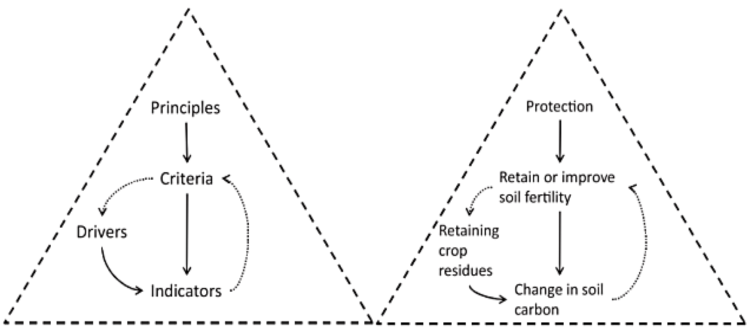

Fig. 1. A conceptual diagram of the causal relationship between principles, criteria and indicators and how drivers can help to identify the link between a criterion and its indicator. Source: (Florin et al. 2014).

3 Methodology

Four main methods were used: literature study, stakeholder interviews, household level surveys for assessment of indicators for sustainability, and final stakeholder workshops. Literature study and stakeholder interview were used to identify the drivers of change of the farming systems in the case study areas. A household level survey was used to assess indicators for sustainability in relation to legumes as pathway for sustainability. Initial results of the studies on drivers of change and the household level indicator study were verified and deepened during final stakeholder workshops in both countries. Finally priority areas for research were identified during these stakeholder workshops as well. Detailed reports of the stakeholder workshops can be found on the N2Africa website (Marinus et al. 2016a; Marinus et al. 2016b).

3.1 Case study areas

Two contrasting research sites within the N2Africa action sites were selected for both case study countries. Diversity in population density, market access, and agro-ecological condition were used as selection criteria for the two research sites within a country (Table 1) as these are some of the main drivers influencing agricultural development (Pender et al. 1999). The two case study countries and their research sites together showed a wide range of population densities (56-1200 inhabitants per km^2), market access (0.5-5 hours), and agro-ecological conditions (uni-modal and bi-modal rainfall patterns and mean annual rainfall of 900-1800 mm).

Table 1. General characteristics of the selected N2Africa action sites (Franke et al. 2011).

	Northern Ghana		Western Kenya	
	Bawku West	Savelugu	Vihiga	Migori
Population density (inhabitants per km^2)	56-103	61-70	1200	300
Access to urban markets (h)	1-3	0.5	0.5	5
Rainfall pattern	Uni-modal	Uni-modal	Bi-modal	Bi-modal
Annual rainfall (mm)	700-1100	800-1200	1800	1360
Important legumes	Soyabean, cowpea, groundnut	Soyabean, cowpea, groundnut	Bush bean	Bush bean, groundnut, soyabean

3.2 Assessing drivers of change

The main drivers of change that have influenced the current status of farming systems in the case study areas were identified through literature study and stakeholder interviews, focussing on the past 20-30 years. The final stakeholder workshops were used to verify and deepen the results of this study. In total 13 stakeholders in Western Kenya and 16 in Northern Ghana were interviewed, including extension workers, local government officials, officials of the Ministry of Food and Agriculture, NGO's, farmer based organizations, and local lead farmers. Furthermore, farmer interviews during the household surveys were used to get a broader understanding on local developments and to triangulate results from the stakeholder interviews.

3.3 Indicators for sustainability at farm level

Indicator selection for the household level assessment of the role for legumes as pathway for sustainable intensification was based on the hierarchical framework of principles, criteria, and indicators (Fig. 1). The identification of principles for sustainable intensification of smallholder farming systems was based on discussions and decided upon during the mid-term evaluation meeting of the PROIntensAfrica in-depth case studies in Dakar, Senegal (April 28-29, 2016). The five principles identified for the In-depth case studies of PROIntensAfrica were *productivity*, *viability*, *resilience*, *social wellbeing*, and *environment*.

A first list of criteria were identified by analysing the Vision of success and the Objectives of N2Africa (Annex I, www.N2Africa.org). Secondly, additional criteria and indicators for sustainable intensification of smallholder farming systems were selected for principles that were not part of the Vision of success or the Objectives of N2Africa (Table 2) and/or that are seen as important indicators for sustainable intensification (Africa Rising 2016).

Data collection

Indicators were assessed using a household survey in which farm characteristics needed for the indicators were captured. All fields used by the household were measured using a handheld GPS and detailed questions were asked on for instance input use and crop yields. Households in Kenya were selected using the N2Africa baseline survey (Franke and Wolf 2011). The main objective for house selection was to get a representative sample of the population in which there was a representative spread in farm structure (cultivated area, valuable assets, livestock owned) among the selected households. For Ghana the N2Africa early impact survey (Stadler et al. 2016) was used for selecting households. Ten households were selected per research site within a country and in Migori three additional households were selected during the survey to incorporate more soyabean-cultivating households. In total 43 households were interviewed for this survey. Surveys took place during the dry season in both countries, in December 2015 and early May 2016 (follow-up) in northern Ghana and in March 2016 in Kenya.

Data analysis and indicator development

A detailed description on how the household level indicators were calculated and what scaling was used per indicator can be found in Annex II. An overview of all indicators assessed, their units and scaling is given in Table 3. Indicators were expressed in a score from 0 to 10. A score of 0 related to 0 or completely insufficient as related to sustainability. A score of 10 related to minimum or good sustainability. This could be for instance to derive a minimum income from farm gross margin, or to have a nitrogen use efficiency between 70 and 90%. To assess the ‘sustainability of a household’ however, the overall interaction between the different indicators for sustainability should be assessed. Farm size for instance was assessed as an indicator for sustainability. A small farm size however could still be sustainable if the production activities are very profitable (while not harming the environment). Indicator results were therefore plotted in a spider diagram to assess possible interaction between indicators per household. Average scores per principle (average across indicators belonging to a principle) were also calculated to assess sustainability of a household on the level of principles. Average scores for indicators and principles for each of the two research sites in both case study countries were used to analyse differences between sites and countries.

Table 2. Household level principles, criteria and indicators. Criteria based on the N2Africa *Vision of success* and *Objectives* are in Italics..

Principles	Criteria	Causal links *Grain legume intensification...*	Indicators
Productivity	*[...] greater food and nutrition security [...]*	... increases availability of (nutritious) food	Protein from legumes Food self-sufficiency
	[...] close yield gaps [...]	... reduces legume yield gaps and thereby eventually also maize yield gaps	Legume yield gap Maize yield gap
Viability	To have a viable farm size		Farm size
	[...] increased incomes [...]	... produces high value grains and therefore improves income	Farm gross margin
	[...] expand the area of legume production within the farm [...]	... increases the proportion of the farm cultivated with legumes	Legume intensity
	Increase or maintain farm assets		Valuable assets Livestock ow
Resilience	Increase or maintain the natural resource base	... *increases N inputs from N_2-fixation* and thereby soil fertility	N input from N_2-fixation
	To spread and reduce risks of crop failure		Agro-diversity Price variability Yield variability
Social wellbeing	*[...] introducing labour saving technologies from which women benefit [...]*	... results in increase labour use efficiency	Share of women in labour
	Empower women [...]	... results in benefits for women as they are often the ones cultivating legumes in the household	Women empowerment
	[...] greater food and nutrition security [...]	... results in higher production and therefore increases food security	Food security
	To reduce post-harvest losses		Post-harvest storage
	To be connected to markets		Market access
	To receive regular extension advice		Frequency of extension services

Table 3. The indicators that were collected in the household level survey and their units. The last column identifies possible other principles under which an indicator could fit. More details and on the units and how indicators were calculated and scored can be found in Annex II.

Indicators	Possible other principles	Units	Scaling	
			0	10
Productivity				
Protein from legumes		% of protein required in diet	0	100
Food self-sufficiency		Months $year^{-1}$	0	12
Legume yield gap		%	100	0
Maize yield gap		%	100	0
Viability				
Farm size		ha	0	5
Farm gross margin		100× (US$ per adult /minimum wage)	0	100
Legume intensity		%	0	50
Valuable assets	*Resilience*	Score	From Njuki et al. (2011)	
Livestock owned	*Resilience*	TLU	0	10
Resilience				
N input from N2-fixation		kg N/ha farm area	0	50
Agro-diversity		Simpsons diversity index	No diversity	High diversity
Price variability		Score	Very variable	Stable
Yield variability		Score	Very variable	Stable
Social wellbeing				
Share of women in labour		%	75	0
Women empowerment		Score	Based on Alkire et al. (2013)	
Food security		Months $year^{-1}$	0	12
Post-harvest storage	*Viability*	Score	No protection	Several measures
Market access	*Viability*	Minutes	120	0
Frequency of extension services	*Viability*	Score	> year ago	Weekly
Environment				
Crop protection use		Score	No use	Use, no measures
N surplus		kg N/ha	Traffic light indicators (EU Nitrogen Expert Panel 2015)	
Nitrogen use efficiency	*Resilience, viability*	%		
Erosion control		Score	No measures	Erosion not likely

3.4 Towards a research agenda

Priority areas for research were identified and discussed during the final part of the stakeholder workshops. Identification of these priority areas was based on the earlier discussed drivers of change and the current status of the farming systems and what role there is for legumes as pathway for sustainable intensification.

4 Drivers of change and their effects on (sustainable) intensification of the farming system

Western Kenya

Population growth and population pressure might be the most important driver of change in Western Kenya. In particular in areas like Vihiga, where population pressure is 1200 persons km^{-1} (Table 1), this has a strong impact on farming systems and the intensification processes. Maize is currently the most important crop in this area and its history of cultivation illustrates how land use has intensified in Western Kenya. Population pressure in Western Kenya has been high since the first written reports about this area. Maize already replaced small grain cereals like sorghum and millet in the 1950's due to its greater productivity, (Crowley and Carter 2000). More than 50 years later this intensification process was still going on. Valbuena et al. (2014) described how in the period from 2003 to 2013 maize cultivation had further intensified by cultivating more hybrid maize varieties. Land use had intensified by the increased cultivation of maize in the short rainy season. The short cropping season was commonly used for cultivating bush bean and fallowing in the past. Valbuena et al. (2014) also described an increase in Napier grass cultivation as fodder for dairy farming. The increased importance of dairy farming was also mentioned during the stakeholder workshops as an important change which is broadly used as an option to increase farm productivity. Population pressure was considered less important as driver of change in Migori during the stakeholder workshop. During the interviews in Migori some households actually mentioned that they, or their ancestors, had migrated from the Maragoli region, of which Vihiga is also part. Migration and working away from home in the cities (Kisumu, Nairobi, Mombasa) have been other ways to cope with the high population pressure in the highlands around Vihiga (Crowley and Carter 2000). Remittances and off-farm income were mentioned during the stakeholder workshops as important sources of income in Vihiga. Off-farm income (salary, pension, remittances) might in turn also be related to increased input use or investment in livestock (dairy) intensification (Tittonell et al. 2005).

Changing market conditions seem to have both negatives and positive impacts on farming systems in Western Kenya. Formerly important 'classical' cash crops like sugar and tobacco became less important due to weak parastatal (sugar) companies and commercial companies that shifted their activities to other countries (for tobacco). Late payment by the parastatal tea company was also named as a reason by interviewed farmers why they reduced the area of tea. One of the stakeholders mentioned that irregular payment from the tea companies is why farmers around Kakamega (the county north of Vihiga) moved to dairy farming as it gives regular income and has an increasing market demand. Soyabean was identified as alternative cash crop by the local county government in Migori that could fill the gap for former tobacco growers.

External development projects and agencies (e.g. One Acre Fund, Agrics) with currently a strong focus on input loans for maize cultivation seem to boost local maize production. Some farmers in Migori mentioned that price peaks had reduced as shortages had reduced as a result of increased production. The focus of many projects on maize was explained during the stakeholder meeting by the interest of farmers in maize (they invest in it as it is their most important food crop). It was mentioned however that maize is not a profitable crop and that continuous maize cropping (current practice) is indeed an issue.

Government policies were rated as very ineffective during the stakeholder meeting. Weak parastatal companies (the earlier mentioned sugar companies) and ineffective national government agencies in the agricultural sector are a common phenomenon in Kenya and their revival (and downturn) is often related to political reasons that seem to have little to do with the interests of smallholder farmers (Poulton and Kanyinga 2014). The National Cereal and Produce Board, that subsidises fertilizer inputs for maize sells, for instance only 50 kg bags. Smallholder farmers however usually buy quantities of 1, 10, or at most 25 kg and can find it difficult to afford 50 kg bags. Also other governmental agencies like for instance the Kenya Industrial Research and Development Institute (KIRIDI) were said to be little effective. KIRIDI operates local soyabean processing plants that can be used by local farmers group. An extension officer near the research site in Vihiga also told how extension work is understaffed. In her office there were supposed to be three extension officers, while she is the only one. This pattern of underfunded extension work, resulting in less people on the ground to advise farmers what to do, seems typical for the Kenyan extension system (Poulton and Kanyinga 2014).

The emergence of **yield reducing factors in legumes was** seen as important by the stakeholders as yield reducing factors were said to occur more in legumes than in cereal crops for instance. Root-rot in bush bean was named as an important example that almost completely wiped out bush bean cultivation in some areas. Dissemination of improved varieties (KK8, by N2Africa) seemed to show limited success.

Northern Ghana

Increasing population pressure was also in Northern Ghana an important driver of change. Effects of this driver differed per area. Upper-east (district of which Bawku West is part) historically already had a higher population density than the Northern Region (of which Savelugu is part). Continuous cultivation instead of a fallow cropping system has therefore been common in Upper East for a longer time, while this change towards continuous cultivation was currently ongoing in the Northern Region (Van Vliet and Van der Kamp 2009). Upper East had historically also seen more seasonal and permanent migration to the cities in the south (Van der Geest 2011). During the stakeholder workshop however it was said that north-south migration has become less important due to increased employment opportunities in Northern Ghana. Intensified land use due to population pressure with maize cultivation as a result was also an important development in Northern Ghana. It was said during stakeholder interviews that so called local 'yellow maize' had been cultivated along with other crops like sorghum and millet as long as people could remember. Higher yielding white maize varieties were introduced in the late 80's and 90's by the Sasakawa Global 2000 project and common since then in the Northern Region. One of these varieties, Obatanpa, was released in 1992 (Badu-Apraku et al. 2006) and was currently still the most commonly cultivated variety for the farmers that took part in the survey. White maize varieties had only become more common in Upper East in the past 10 years and mainly replaced small grain cereals like millet and sorghum. Reasons named for this change were the better responsiveness of maize to fertilizers and the reducing yields of small grain cereals. Hybrid maize varieties are imported and not commonly used yet in Northern Ghana.

Improved availability of inputs was confirmed as a driver of change of farming systems in Northern Ghana during the stakeholder workshop. The state owned agro-input sector that heavily supported agricultural production in the 1970's had completely been cut back during the structural adjust programs of 1980's (Jansson 2004 as cited in Khor 2006). By 1990 fertilizers were not subsidised anymore and agro-input supply was left to the commercial sector. This led to reduced input availability and reduced use of inputs as several stakeholders explained. Only in the past decade mineral fertilizers and agro chemicals became more widely used again in Northern Ghana. One agro-input dealer explained that when he started his business in Tamale in 2001, the number of agro-input dealers were very few and as he was saying: "Now they can be found everywhere". A similar story was told by an agro-input dealer in Zebilla (Bawku West). When he started six years ago he was the first, now there were several in town. A survey done by IFPRI (Fig. 2), showed however that the number agro input dealers in Northern Ghana is still far less than in the south and that most of them are concentrated around the main towns and roads.

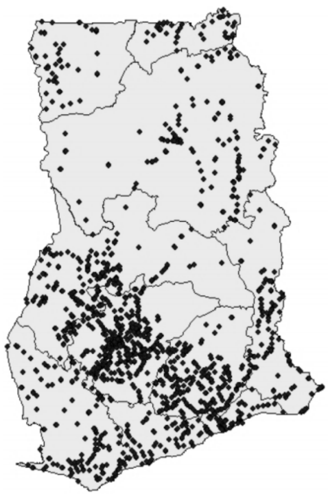

Fig. 2. Locations of agro input dealers in Ghana (Krausova and Banful 2010)**.**

Government policies were seen as **ineffective** or having little effect on agricultural development during the stakeholder workshop. Reduced growth of the agricultural sector was mentioned as an example. Renewed investment in the agriculture sector including for instance subsidised fertilizer and tractor ploughing services (Krausova and Banful 2010; Diao et al. 2014) were seen as important, but little effective. Private tractor ploughing services by small business men and larger farmers were for instance seen as more important than the subsidised services provided through the Ministry of Food and Agriculture. The fertiliser subsidy scheme increased fertiliser use, but the coupon system that was used up to 2015 only reached a limited number of farmers and fertilisers were often delivered late. The new system in 2016 required new registration of farmers and the use of mobile phone text messages. Many farmers do not know how to use text messages, which might again make that only limited number of farmers benefits from subsidised fertilizer. Participants also pointed out the poor funding of the agricultural sector by the government. National research institutes and government extension service for instance largely depend on funding from donors, not the government. Furthermore, budgetary allocation from the Ministry of Food and Agriculture (MoFA) to local branches (extension services) does not always come or arrives late, resulting in immobility of Agricultural Extension Agents (AEA's). At the same time many areas are understaffed in terms of AEA as retiring AEA's were currently not replaced.

External development agencies/projects seem to take an important role in agricultural development and extension. Increased production of soyabean and an increase in areas with in irrigated vegetables was for instance seen as a result of external development agencies/projects. Private sector led (WIENCO and YARA) initiatives like the Masara N'Arziki program (Hausa for prosperous maize growth) was seen as a program with mixed results. Farmers receive fertilisers and hybrid maize seed on credit and can sell back their maize to Masara N'Arziki for guaranteed prices. Repayment of inputs was said to be a problem, although some participants in the stakeholder workshops also described this as initial problems and that currently the number of participating farmers was growing.

Climate change was also seen as an important driver of change in Northern Ghana, resulting in more erratic rains and less cultivation of early millet (Upper East) and yam (Northern Region). The reduction of these crops was said to be another reason why the cultivated area of maize had increase.

Improved education was identified during the workshop as an additional driver of change. It has led to a better-educated youth, of which an increasing proportion does not want to go into farming anymore. In addition, the decreasing farm size due to population pressure makes farming less profitable. This further reduces the willingness of youth to go into farming. But also offers opportunities for farming as a business for those who stay in agriculture to cultivate larger areas.

5 Current status: Sustainability of farming systems at household level – what role for legumes?

Spider diagrams were used to compare indicator scores between research sites (Fig. 3C, D) and relate legume intensity (the percentage of cultivated area of a household cultivated with legumes) to these indicators for sustainability (Table 3). Indicators were expressed in a score of 0-10, where 0 is related to low sustainability and 10 is related to high sustainability (detailed descriptions of the indicators can be found in Annex II). Indicators in the spider charts were grouped according to the principles they belonged to (Productivity, Viability, Resilience, Social wellbeing, Environment). Average scores (across indicators) per principle were also calculated (Fig. 3A, B). Considerable variation was found in indicator results between household within a research site (Annex III and Annex IV). This means that averages across households as shown in Fig. 3 and Fig. 4 should be treated with caution as is further discussed in *5.4 Challenges for interpreting indicator results*. Averages across households and some individual household results were used during the stakeholder workshops to discuss, verify and deepen the understanding of the results.

5.1 Comparing case study countries

Average scores on the level of principles were below 6 for nearly all principles in both case study countries (Fig. 3), meaning that sustainability of interviewed households could be considered low or just sufficient. Outcomes on the level of principles were very similar between countries and between research sites within a country. Only viability was considerably lower for Western Kenya than for Northern Ghana, which was caused by lower scores for all underlying indicators (Fig. 3C and D, farm size, farm gross margin, legume intensity, valuable assets and livestock owned). The lower score for viability in Western Kenya might be related to the high population density in Western Kenya, resulting in less space for farming. Stakeholders and literature confirmed that due to small farm sizes, smallholder farmers in Western Kenya focused on producing for own food self-sufficiency and therefore cultivate more maize as it is the most important staple crop and produces more calories per ha than legumes. The farm gross margin score was lower in Western Kenya due to the higher minimum wage (which was used as upper boundary for a score of 10) in Western Kenya than in Northern Ghana.

On the level of indicators

The legume (and maize) yield gap scores were more positive (smaller yield gap) for Western Kenya than for Northern Ghana. This could indicate that yield intensification in Western Kenya is higher than in Northern Ghana. Higher intensification levels in Western Kenya might be related to its denser population and better developed agriculture than in Northern Ghana. In contrast, the protein from legumes indicators for Northern Ghana was almost double that of Western Kenya. This was caused by the relatively bigger difference in the proportion of the farm cultivated with legumes (legume intensity) in Northern Ghana, which resulted in a stronger effect than the higher yield intensification in Western Kenya. The importance of soyabean was the main reason for the higher legume intensity score in Northern Ghana. N input from N_2-fixation on farm level was low (below 9 kg N ha^{-1}) in all sites due to low legume yields (both sites) and low legume intensity in Western Kenya. Inoculants for soyabean were only used by one household (out of 23) in Western Kenya and two households (out of 20) in Northern Ghana. Furthermore, no P-based fertiliser was used in sole legumes. Increased use of inoculants and P-based fertilisers could therefore still increase N input from N_2-fixation in both case study countries. Crop protection use was more common in Northern Ghana than in Western Kenya, resulting in a lower score for Northern Ghana as many farmers did not know what they applied or did this for instance without protective clothing. The market access score was as expected higher in Western Kenya than in Northern Ghana. Low indicator scores in for N surplus and nitrogen use efficiency in both countries were mainly caused by low Nitrogen input levels. Only 2/23 households in Western Kenya and 3/20 in Northern Ghana had a nitrogen use efficiency that was below 50% (risk of losses to the environment), while 10/23 households in Western Kenya and 5/20 Northern Ghana had a nitrogen use efficiency above 90% (risk of soil mining).

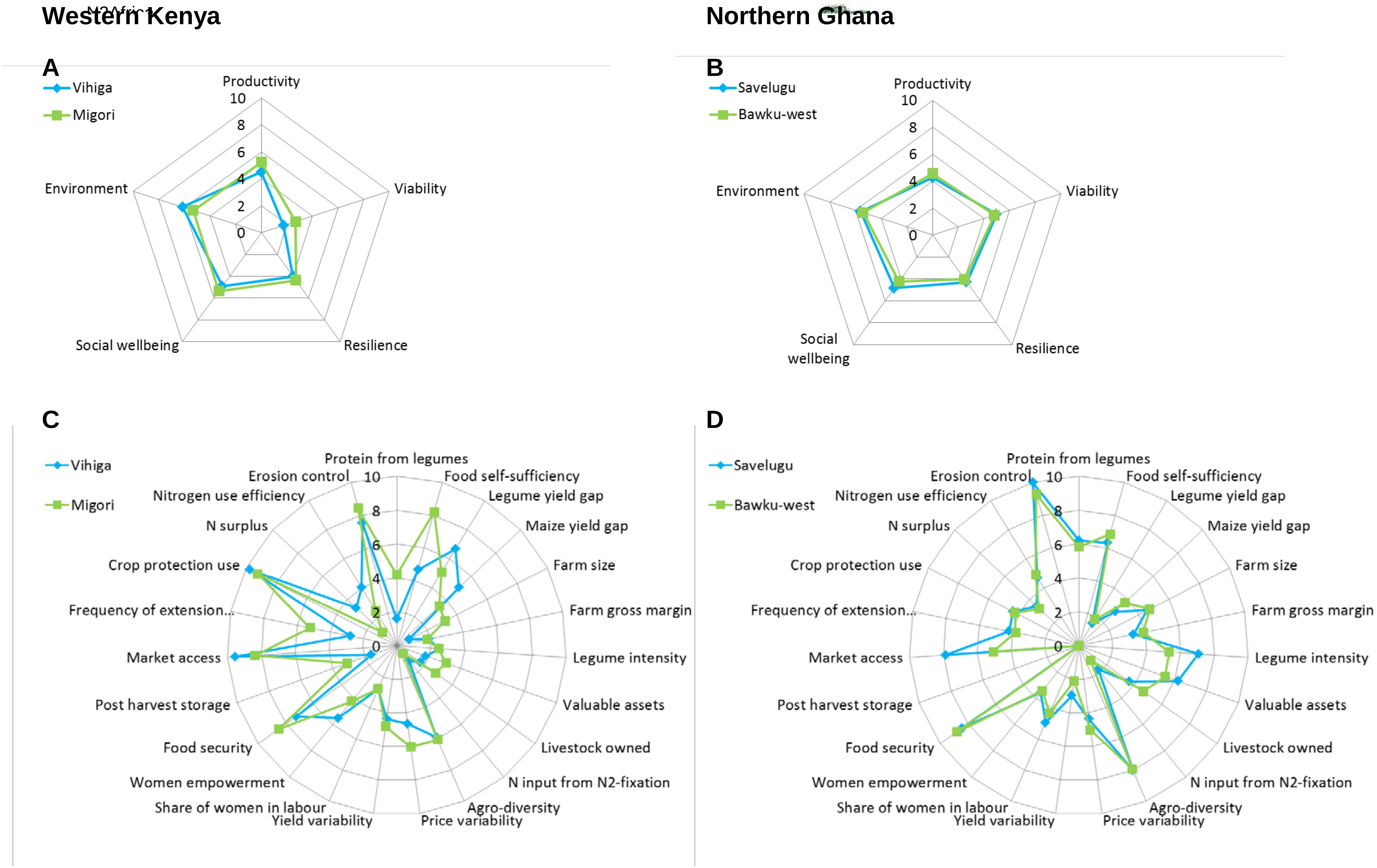

Fig. 3. Average results across all households per research site in Western Kenya (A, C) and Northern Ghana (B, D). Indicators for sustainability were aggregated on the level of principles using equal weighing for the outcomes of each indicator (A, B). Outcomes for all indicators for sustainability are shown in C and D.

5.2 Sustainability indicators per research site

Western Kenya
Vihiga was selected as an area with higher population densities, smaller farm sizes and better market access than Migori. Indicator scores for market access was as expected better and farm size smaller in Vihiga than in Migori. (Fig. 3). The food self-sufficiency indicator was almost 4 points higher for Migori than for Vihiga, which can be related to the difference in farm size, resulting in more crop production for food self-sufficiency in Migori. For the food security indicator however, this difference was less than 2 points. Furthermore, the farm gross margin indicator resulted in very similar outcomes for both sites. Food security in Vihiga, when compared with Migori, therefore seems to be based more on off-farm income or other indirect sources of income from the farm that contribute to household income and thereby to food security. In particular dairy farming, and for two households, tea cultivation were important sources of income from the farm in Vihiga that could contribute to food security. Intensification of dairy farming was indeed confirmed during the stakeholder workshop as an important source of income in Vihiga. Participants mentioned furthermore that remittances (from e.g. Mombasa, Nairobi), horticulture and the larger prevalence of small businesses and value adding activities were important sources of income in Vihiga. It was also discussed whether the current mode of intensification as practiced in Vihiga (more dairy cattle, higher yields) could be an option for other areas in western Kenya (like Migori). Participants commented that Vihiga is closer to urban markets (e.g. Kisumu), which provides different opportunities than in Migori and therefore less options for dairy intensification in Migori. It was also noted that the larger farm sizes (indicator result) in Migori also allows for other cropping systems with a stronger focus on surplus production (e.g. soybean), while in Vihiga the small farm sizes leave many farmers to focus on food self-sufficiency (through maize).

Small (and still decreasing) farm sizes were confirmed to be a major issue, in particular in Vihiga. A government policy on this was once proposed (fields smaller than 0.25 acre were not allowed to be sub-divided any further) but never implemented. “People will always continue to subdivide” as it was said. Stronger policies would be needed to stop this trend. One of the effects of decreasing farm sizes that was noted was the ongoing process of intensification, which might be the reason for smaller yield gaps in Vihiga than in Migori.

Activities of One Acre Fund in Migori were the single reason why the indicator score for frequency of extension services was larger for Migori (10/13 took part in One Acre Fund) than for Vihiga (2/10 took part). Households that took part in One Acre Fund activities attend weekly meetings with their farmers group, which is often also attended by an extension worker from One Acre Fund. Almost no other projects (N2Africa in 2013 was the last one that was remembered) or governmental extension services were mentioned in Migori. In Vihiga veterinary extension workers from governmental agencies and extension from parastatal tea companies were still active. Extension and credit services like One Acre Fund were seen as an important method for intensification during the workshop.

The difference in protein from legumes score between Vihiga and Migori was mainly caused by two households (out of 13) that reported exceptionally high bush bean yields (approximately 2000 kg ha^{-1}, while the median was 400 kg ha^{-1}) in Migori, which resulted in very high protein from legumes scores.

Northern Ghana
Indicator results showed very similar outcomes for Savelugu and Bawku West. Only scores for legume intensity and market access were considerably higher for Savelugu. Soyabeans were the most important legume to make up this difference in legume intensity. Savelugu is close (20 minutes driving to Tamale, the main trading hub in Northern Ghana, from where soyabeans are sold to the south of Ghana.

Particularly low indicator scores (<4) were found for maize and legume yield gaps, farm gross margin, N input from N_2-fixation, yield variability, women empowerment, post-harvest storage, frequency of extension, and N surplus. No methods for improved post-harvest storage were used with the interviewed households in Northern Ghana, resulting in a score of 0.

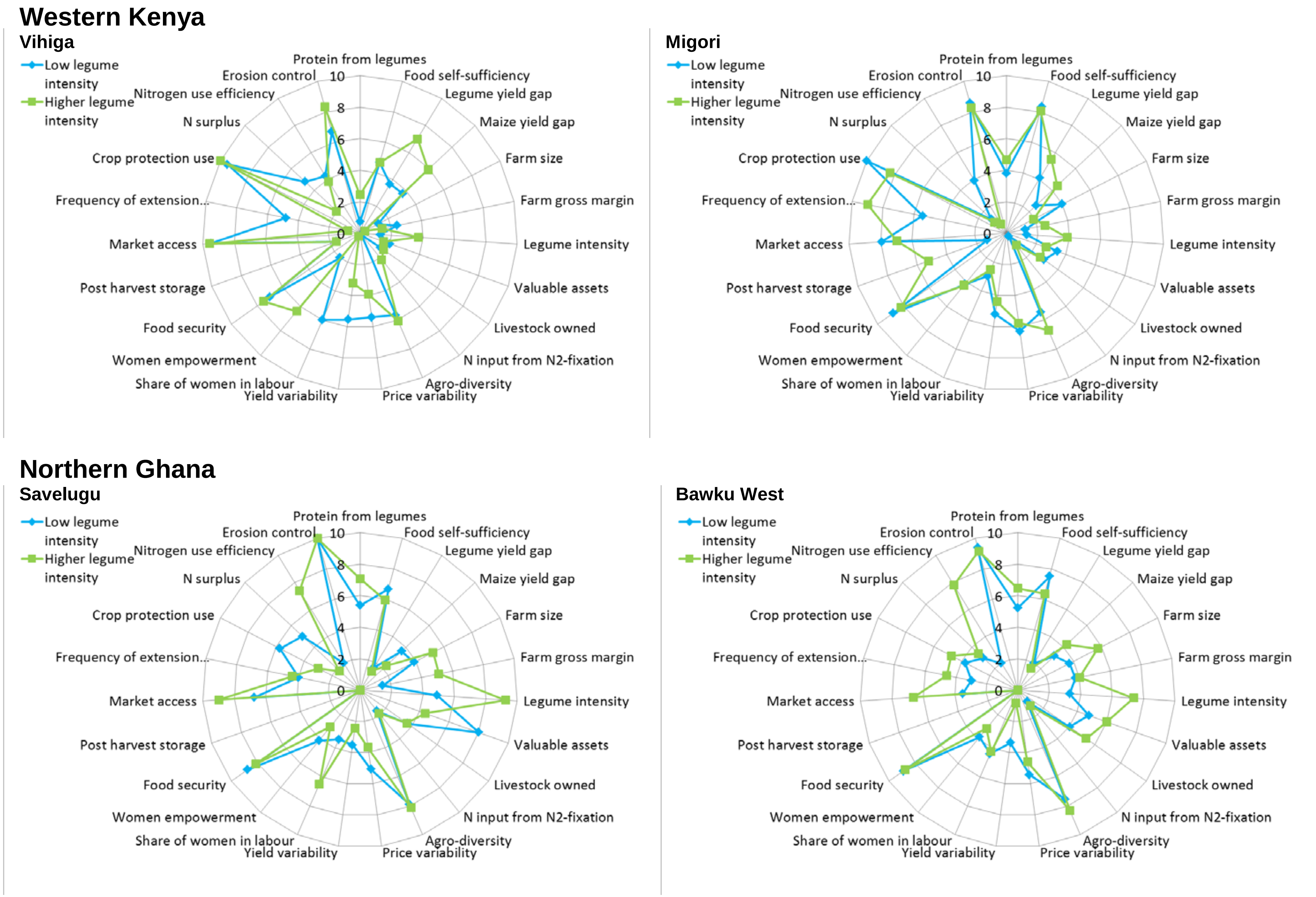

Fig. 4. Average indicators scores for households with a low legume intensity score and a high legume intensity score (averages cross respectively the 50% of the households with the lowest and highest legume intensity) per research site in Western Kenya and Northern Ghana.

5.3 Legume intensity as related to indicators for sustainability

Households per research site were divided into the 50% of the households with the lowest and the highest legume intensity to assess possible relations between legume intensity and indicators for sustainability. No consistent relations between legume intensity and other indicators for sustainability across all research sites in both case study countries were found (Fig. 4). The difference in legume intensity between the households with low and high legume intensity was bigger in Northern Ghana than in Western Kenya. However, due to low legume yields, this resulted in only limited impact on N input from N_2-fixation in Northern Ghana.

There seemed to be some relations between legume intensity and indicators for sustainability between research sites within a country. Indicator scores for yield gaps of legumes and in particular maize were more positive for households with a higher legume intensity in Western Kenya than a low legume intensity. Such a relation was not found in northern Ghana, which might be the result of differences in agricultural practices: soyabean in Northern Ghana is often cultivated in particular fields (sole cropping) with limited rotation, while maize in Western Kenya is commonly intercropped with bush bean (which is the most commonly cultivated legume). Households with a higher legume intensity had higher indicator scores for farm size, nitrogen use efficiency, and market access in both research areas in Northern Ghana. Participants of the stakeholder workshop in Northern Ghana confirmed that farmers with more land cultivate a larger share of their land with legumes, in particular with soyabean. Soyabean is mainly considered a cash crop by these farmers, which might explain the higher score for market access for households with a higher legume intensity. A higher score for nitrogen use efficiency for households with a higher legume intensity was the result of higher nitrogen inputs for these households, which came both from N_2-fixation and mineral fertilisers.

5.4 Challenges for interpreting indicator results

Some general patterns were noted when analysing the outcomes of the indicators for sustainability. There was a lot of variation in outcomes within a research site when comparing the individual results per household on the level of indicators (Annex III and IV). Averages of indicators across households per research site however, showed very similar patterns within a country and limited differences. Also, less variation was found when assessing the scores on the level of principles (averages across indicator scores belonging to a principle) then on the level of indicators, both when comparing between households and between research sites within and between case study countries.

The enormous variation between households within a research site on the level of indicators suggests that the averages within a research site or on the levels of principles might (at best) only give an indication for general trends. It seems however crucial to study and understand individual household results on the level of indicators in future research. Comparing individual results to average results in the research area could help to understand why certain indicators score very high and others very low. Furthermore, the highest scores in an area could for instance be seen as the attainable score within the given socio-economic and agro-ecological circumstances of that research site and be used as a benchmark. Discussing and assessing the reasons for high and low scores of an indicator could lead to the identification of entry points for improvements on that indicator for sustainability.

6 Towards a research agenda

Priority areas for research were identified during the stakeholder workshop, based on the drivers of change and results of the household survey. In this chapter, the priorities for research are divided into two sub-sections: 1) Priority areas for research on the role of legumes in sustainable intensification, and 2) Priority areas for research on sustainable intensification of farming systems in the case study areas. These parts are separated to emphasize that possible pathways for sustainable intensification, legumes in this case, should be assessed in the light of the farming systems in which they have to fit.

6.1 Identifying priority areas for research – Western Kenya

Priority areas for research on the role of legumes in sustainable intensification

How to have knowledge, as specific as possible, **available for farmers and being able to transfer that knowledge**, was an important knowledge gap that came back in many topics. For instance in the case of legumes the question was posed, "*Which specific legumes can be grown in which area?*" This was specifically asked in relation to the diversity of agro-ecological conditions in Western Kenya and the diversity of legumes is available, from green gram to climbing bean and from groundnut to bush bean, all with a range of varieties. Climbing bean was discussed as an example as a possible option for the highly populated highland areas around Vihiga. Furthermore, participants discussed the importance of being able to **predict realistically legume yields in farmers' fields**. The question was, "*If we advise a farmer to grow soyabean and use Sympal (P-based fertiliser) and inoculants, can we estimate what the yields and profitability will be for him or her?"* This was discussed in the light of **facilitating farmers in well informed decision making and reducing the risks they take when using inputs**. Participants saw this as important as farmers had been using legume inputs but were disappointed in the yields and/or profits that they were making, which sometimes made farmers hesitant to use inputs or cultivate legumes in future. ICT or mobile phone platforms were discussed as important option to transfer such knowledge to farmers or extension agents. Another point that was discussed on transferring knowledge to farmers and that could make use of ICT platforms was **the importance for farmers to be informed about market demand and prices**, which links to the well informed decision making described before. In particular for crops like soyabean, for which the national or regional and not the local markets are important, it is important for farmers to know which price they can get where for the crop they want to sell. Increasing the knowledge on current prices and demand could help to reduce the current gap that exists between farmers that want to sell their soyabean produce and big buyers that are looking for soyabean but do not know where to find it. **Strengthening farmer groups** might be an additional option to overcome this gap.

"***What is the economic viability of legumes as part of improved crop-livestock systems and in comparison with classical cash crops****?*" was posed as a research question that could link the search for alternative cash crops and the upcoming importance of dairy farming in Western Kenya. The high nutritional value of legume fodder and/or residues could be of benefit for intensifying dairy farming systems, in particular for poorer or middle class farmers that are not able to buy external inputs like concentrates.

Labour saving in soyabean and groundnut harvesting and threshing was seen as another priority area for research. Mechanisation was seen as an important option to address this current constraint for legume intensification.

The role of the government was seen as key to institutionalize legume cultivation and came back in many of priority areas for research that were mentioned before. Specific knowledge, for instance through ICT platforms, should be available for government and other extension workers. Additionally, the importance of making legumes part of government policies was discussed. The example of the **soyabean stakeholder platform** in Migori was seen as an important example. Having such platforms at county level (the government level that is currently responsible for extension work and other agricultural policies) could be a low-key and flexible. These platforms could also be a way to connect stakeholders (e.g. buyers and farmer groups) or to lobby for input subsidies on legume inputs (P-based fertilisers, inoculants).

Priority areas for research on sustainable intensification of the farming systems

The above research topics should all be seen in the light of a further increase of population pressure in the region. **The effect of population pressure on agricultural production** was identified as an important priority area for research during the stakeholder workshop, with questions like: "***Should everyone participate in farming, or only a few committed people?***" and "***How can land fragmentation be halted and eventually land consolidation take place?***".

6.2 Identifying priority areas for research – Northern Ghana

Priority areas for research on the role of legumes in sustainable intensification

The priority areas discussed during the stakeholder workshop in Northern Ghana were nearly all of N2Africa's current focus points, starting with crop-configurations in intercropping and moving up in scale to market systems and government involvement.

Local legume cropping systems often involve legume-cereal intercropping systems (e.g. cowpea-millet or cowpea-maize). Options for sustainable intensification could build on these systems and further improve them. This could for instance result in doing **research on optimal intercropping configurations in space and time** (e.g. relay cropping) **for cereal-legume intercropping systems**.

Finding ways to make (existing) **knowledge available on safe and judicious crop protection agent use in cowpea** (but also for other crops and herbicide use), was another key priority area for improved management on field level. Making this knowledge available however, also involves the need for good extension methods. In particular for cowpea, crop protection use is necessity to obtain good yields, but farmers are often not aware of good management practices, as was also found during the household survey ("*farmers just use anything*" as a stakeholder confirmed).

Availing knowledge for extension about legume response to input use was another combination where field level effects were linked to extension. During the workshop questions were raised about the response and profitability of P-based (TSP) fertiliser and animal manure. Research has been done within N2Africa and results are available for similar agro-ecologies (Ronner et al. 2015) for the response on P-based fertiliser. Discussion during the stakeholder workshops showed however, that work remains to be done on making such knowledge available for extension workers for instance.

How to increase availability and affordability of legume inputs (seeds, P-based fertiliser, inoculants) was discussed as a research topic on market and policy level. Improved groundnut and cowpea varieties have been developed by researchers, but in the past seasons they had not been available to farmers as seeds were not multiplied and therefore not available for agro-input dealers. Although legume seed availability has improved in preparation for the 2016 cropping season in a joint effort of legume breeders, seed multipliers, seed traders and MOFA seed inspection unit, led by the N2Africa team, legume seed availability remains a point of attention. Reuse of legume seed is common practice by farmers, which is why multipliers do not multiply and agro-input dealers do not stock legume seeds. **Methods have to be found on how demand can be created (farmers should be informed about new varieties) and how this demand can be met (seed multiplication and seed availability with agro-input dealers), when new varieties are introduced.** The current concentration of agro-inputs dealers around main roads and big towns (Fig. 2) was discussed as a constraint for which alternative modes of supply should be found. The current effort of Greeneff (company that started in 2016 to supply legume inputs to **agro-input dealers**) also asked for such **alternative supply chains**. They were planning for supply of inoculants (perishable, need cooling) on demand just before the planting season in cooperation with local farmer groups. In relation to the policy level, profitability of **P-based fertiliser** and the high price of these fertilisers (**not subsidised**, while fertilisers for cereals are subsidised) was discussed and the question was raised on **how to involve the government** in this.

Developing labour reduction technologies for harvesting and threshing soyabean could be another priority area for research as it is an important constraint for cultivating soyabean. Mechanisation was seen as an important option and could be linked to the earlier mentioned tractor services of MOFA or other service providers.

Identifying options for value addition through small or medium scale processing enterprises was identified as priority area for research for marketing soyabean. Currently most soyabean is sold to processing companies in the south, of which part of the processed products are sold again in the north. A large scale oil mill in Tamale that was established years before was not able to succeed and out of operation at present. Small or medium scale enterprises could however be an option in which also local employment could be created for the increasing population.

Priority areas for research on sustainable intensification of the farming systems

Increasing population pressure and reducing interest of youth in farming was discussed as a combined priority area for research. The following chain of reasoning was brought up: if more people go out of farming, more space might be available for the remaining farmers. Through increased education levels these remaining farmers might have a better education. Combining these developments might result in a window of opportunity for **'farming as a business'**. There are however many unknowns in this reasoning, while the outcomes of all these developments are of utmost importance for the next generation of farmers and future food security in the region.

Crop-livestock integration was also seen as a priority area for research. Livestock systems (cattle herding) and cropping systems are currently not linked. Livestock is mostly owned and always herded by the Fulani people. Even if Dagomba people own cattle, this is still herded by the Fulani. Integrating these systems could therefore be an important option for soil fertility management and therefore for sustainable intensification.

Climate resilient cropping practises like cultivating more crops to spread risks, (aspects of) conservation agriculture for the drier north, and short duration varieties, were identified as priority areas for research to combat climate change. Later onset of rains and more drought spells were already said to have impact on cropping patterns in Northern Ghana, resulting in reduced cultivation of yam and early millet in Northern Region and Upper East respectively.

Area specific fertiliser recommendations were discussed as the final priority area for research. Current blanket recommendations of three bags of fertilisers for maize were said to often result in losses and a scientific basis was questioned.

7 Concluding remarks: Similarities and diversity in Western Kenya and Northern Ghana

The need for integrated options were key in both case study countries and exemplified the need for embedding pathways for sustainable intensification, such as the use of legumes, in all system levels. This is analogous to what Ojiem et al. (2006) described as the socio-economic niche. While for instance in Northern Ghana value chain support for legume seed productions proved key, in Western Kenya stakeholder platforms on county level were demonstrated to be a valuable method to develop soyabean as alternative cash crop. Both of these integrated solutions aimed to strengthen farm level productivity and used legume technologies as developed and supported by the N2Africa project.

The wide variation in the indicators for sustainability among households once more emphasized that such integrated solutions should consider the enormous diversity that exists in smallholder farming systems in SSA. Considering this diversity is needed to fill the basket with ‘best fit’ options that farmers can use to sustainably intensify their farming systems.

Indicator analysis helped to understand the relations between legume intensity and other indicators for sustainability and highlighted possible bottlenecks and priority areas for research. Although households with a greater legume intensity had a larger nitrogen use efficiency in Northern Ghana, this did not go hand in hand with larger maize yields (while greater legume intensity seemed to result in larger maize yields in Western Kenya). The lack of effects of legume intensity on maize yields in Northern Ghana needs more research to understand the causes of this bottleneck and to improve productivity as well as environmental indicators (NUE). Possible options for improvement could be a stronger emphasis on improved crop rotation and intercropping options. The small farm sizes in Vihiga indicated the need for developing specific legume options (e.g. intercropping climbing bean or soyabean in existing farming systems) that do not reduce maize production (for food self-sufficiency). The lesser legume intensity for farming households with a smaller cultivated area in Northern Ghana requires research to understand the cause of this relation and to find legume options that fit for these smaller farms.

The two case studies also showed similarities in the current constraints for integrated solutions to capture existing diversity, which is discussed in the remainder of this section. In both case study areas extension workers and NGO’s expressed a need for more specific recommendations. In Western Kenya there was a request for very specific advice on which legumes could be grown where, with which expected yield and profitability of input use. In Northern Ghana the questions were more generic: to replace the current blanket recommendation for fertiliser use on maize with area specific recommendations.

Questions on how crop-livestock integration could be enhanced arose in both case study areas, but with different objectives. In Western Kenya the main focus was on the profitability of legumes in crop-livestock systems and how this could increase livestock productivity. In the Northern Region of Northern Ghana however, the emphasis was on making use of animal manure and linking livestock and cropping systems, as this is rarely done at present.

Labour saving technologies were also seen as key for legume intensification and linked to the need for research on more profitable cropping systems in both Western Kenya and Northern Ghana. The reduced or low profitability of farming also linked to the need for alternatives sources of employment for those who are ‘stepping out’ (Dorward 2009) of farming. Stakeholders mentioned that although value addition activities and agro-processing of legumes might provide some employment, most employment opportunities will have to come from sectors and government led developments outside agriculture.

The importance of involving government bodies in the development of options for sustainable intensification was also highlighted in both countries, while at the same time weak government policies on agriculture and their poor implementation were seen as important constraints. This contradiction points at the difficulty of developing integrated solutions in these policy environments, which will not only need more research on sustainable intensification, but also more commitment of the relevant government authorities.

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Annex I - Criteria of N2Africa based on its Vision of success and its Objectives

(Italic is from the objectives of N2Africa and 'normal' is from the N2Africa vision of success)

At household level
Direct beneficiaries of N2Africa are the farming households with increased benefits from BNF, such as **greater food and nutrition security** or **increased incomes**.

*4: Tailor and adapt legume technologies to **close yield gaps** and **expand the area of legume production within the farm***

*3: **Empower women** to increase benefits from legume production*

*Strategic gender activities include introducing **labour saving technologies from which women benefit**, recognition of women as key players in the value chain and creating market opportunities that can benefit women.*

*To **improve the nutrition security of women and children**, we adapt household level processing technologies for the production of nutritionally improved traditional and legume-based novel food products*

*Within these boundaries, we try to identify the niches for legumes in the farming systems, tailor and **adapt legume technologies to specific sites and specific farmers**, and translate 'best fit technologies' at the field-scale into a set of 'best-fit approaches' at the country or regional scale.*

At project/regional level
We align with key partners and widen our partnership with NGOs and extension services, allowing us to reach a much larger number of farmer households and effectively scale out legume technologies.

N2Africa engages with the private sector to ensure a stable supply of agricultural inputs such as seed, fertilizer and inoculant, and by linking farmers to output markets, amongst others through adding value to legume produce

N2Africa functions as a 'knowledge broker' and makes the project's knowledge available to the wider public.

Other direct beneficiaries of the project are agro-dealers supplying agro-inputs, seed producers engaged in the legume seed sector, staff from development agencies who benefit from hands-on capacity building activities, national system scientists who are exposed to new ways of doing science through the 'development-to- research' framework, and the private sector engaged in the production and promotion of inoculants and legume-specific fertilizer.

By working through national systems, by training of all key stakeholders from farmers to traders, development workers in extension and NGOs, and by educating MSc and PhD candidates in each country, we build the capacity that can in the future sustain an independent and continuous improvement of legume production technologies.

Depending on the strength and sustainability of the local interest, we work to facilitate import or local production of high quality inoculants, including local quality control systems.

...and to translate 'best fit technologies' at the field-scale into a set of best-fit principles and options for each project area.

Annex II – Household level indicator description

Protein from legumes

The protein from legumes indicators is an indicator for the contribution of legumes to protein self-sufficiency of the household. The total amount of proteins from legumes was calculated based on the protein contents of the different grain legumes (Table 4) and the farmer reported production of these legumes in the previous year (2015). Protein requirements of the household were calculated as the sum of the protein requirements of all household members. Protein requirements per household member were based on the Protein Save Level (the level needed per person at which 97.5% of the population receives enough protein) for active persons, differentiated for men and women and calculated from an assumed bodyweight-age relationship for different age groups (Table 5, personal communication, Ilse de Jager). The protein from legumes indicator was than calculated as follows (with a maximum of 10):

Table 4. Grain protein contents (USDA 2016) of grain legumes cultivated by households in Kenya and Ghana.

Crop	Protein (g/100 g)
Common bean	20.3
Soybean	35.6
Green gram	23.9
Cowpea	23.5
Groundnut	25.8

Table 5. Body weights and Protein Save Levels for active persons (WHO/FAO/UNU 2007), differentiated for females and males per age group.

Age group	Females		Males	
	Weight (kg)	Protein Safe level (g/day)	Weight (kg)	Protein Safe level (g/day)
0-1	10	10.8	10	10.6
1-3	12	11.3	12	12.2
4-6	19	16.2	20	17.1
7-9	29	26.2	28	25.9
10-14	46	41.0	45	40.5
15-18	56	47.4	67	57.9
19-100	60	50.0	70	58.0

$$\text{Protein from legumes indicator} = 10 \times \frac{\text{Protein production from grain legumes in 2015}}{\text{Household protein requirements per year}}$$

Food self-sufficiency

The household food self-sufficiency indicator was adapted from the Months of Adequate Household Food Provisioning (MAHFP) indicator (Swindale and Bilinsky 2010) that is also used for the food security indicator (see below). The difference however is that for the food self-sufficiency indicator it is asked to the responded which months of the year the majority of the food that is consumed, comes from the own farm. The food self-sufficiency indicator is then calculated as the proportion of the months in a year in which most of the food comes from the own farm:

$$\text{Food self-sufficiency indicator} = 10 \times \frac{\text{Months food self-sufficient}}{12}$$

Legume yield gap

The difference between farmers reported yields and attainable yields of common bean and soybean in Kenya and soybean, groundnut, and cowpea in Ghana was used to estimate a yield gap per legume per farm. The attainable yield of the different legumes was based on the average of the 10% highest yields obtained in N2Africa agronomic trials (Table 6). A weighted average legume yield gap per farm was calculated based the cultivated area of the different legumes per farm, which was then used to calculate the legume yield gap indicator per farm (Fig. 5).

Maize yield gap

For the maize yield gap a similar methodology as for the legume yield gap was used. Attainable yields were however based on results found in literature for the two case study areas (Table 6).

Table 6. Attainable grain yields for the cultivated legumes in Kenya and Ghana and for maize.

	Kenya	Ghana
Soybean[1]	1993	3611
Common bean[2]	630	
Groundnut[1]		1415
Cowpea[1]		2346
Maize[2,3]	5206	3500

[1] 90th percentile of grain yields in N2Afrca agronomic trials (on farm, researchers managed.

[2] 90th percentile grain yields of maize and bush bean (in intercropping with maize) in western Kenya (Ojiem et al. 2014).

[3] Estimated based on the 90% probability with optimal fertilizer application in northern Ghana (Fosu et al. 2012).

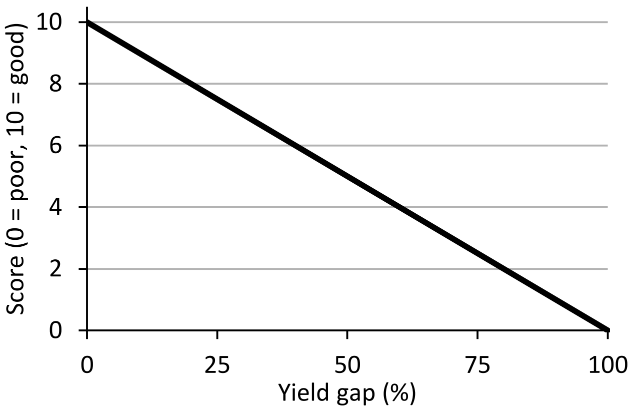


Fig. 5. Yield gap indicator score as related to maize and legume yield gaps on farm level.

Farm size

Farm size was assessed by measuring all fields currently owned or used by a household (including fallow and grazing plots). Fields were measured using a tape measurer if they were smaller than 20×20 m and measured using a hand-held GPS if they were bigger than 20×20m. Farmer estimated field size was used for fields in Ghana that were too far away or hard to reach. Farmer estimates for far away fields were always compared to farmer estimates and measured fields size (of fields closer to the homestead) to correct for systematic over- or underestimations.

The farm size indicator score linearly increased with farm size starting at 0 for 0 ha and a score of 10 for 5 ha (Fig. 6). A farm size of over 5 ha also resulted in a score of 10.

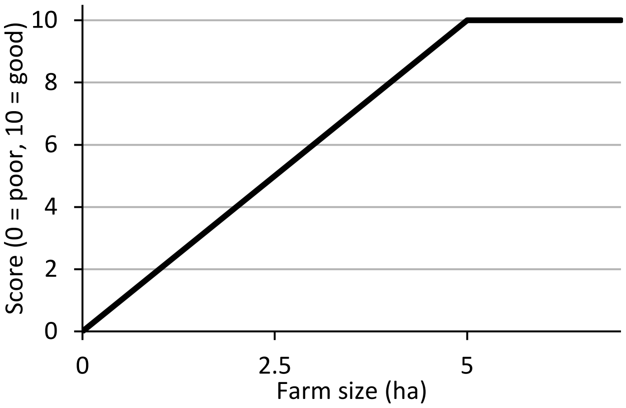


Fig. 6. Farm size as related to the indicator score.

Farm gross margin

Farm gross margin was calculated as the cross revenue from farm activities (crops and livestock sold) in 2015 minus the cost (inputs bought, labour hired) made for these activities. The farm gross margin was divided by the number of people working on the farm to derive the farm gross margin per person working on the farm. The upper boundary (a score of 10) for the farm gross margin per person working on the farm was set at the minimum wage for government workers in both countries. Minimum wages were Kshs 10,955 per month (USD 108.17) for Kenya and GH₵ 216 per month (USD 54.15) for Ghana (minimum wages from http://www.wageindicator.org/ and exchange rates from xe.com, both retrieved on 20-9-2016). The farm gross margin indicator was than calculated using the following formula with a maximum of 10:

$$\text{Farm gross margin indicator} = 10 \times \frac{\text{Farm gross margin per person working on the farm}}{\text{Minimum wage}}$$

Legume intensity

Legume intensity in the previous season (the percentage of the cultivated land cultivated with legumes per farm) was used as indicator for optimal crop rotation in which 50% of the farm is cultivated with legumes and 50% with other crops (Fig. 7). The total with area with legumes in the previous season divided by the total cultivated area in that season was used to estimate the legume intensity per farm. Fixed percentages were used to estimate the cultivated area per crop if intercropping was used (66% for the first crop and 33% for the second crop, any third or fourth crops were not taken into account) as farmers found it too difficult to estimate the percentage intercropping in the previous season.

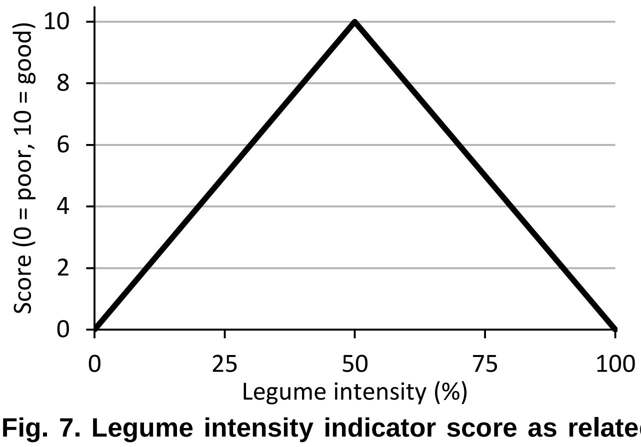


Fig. 7. Legume intensity indicator score as related to the legume intensity (percentage of the total cultivated area cultivated with legumes) in the previous season.

Valuable goods

The three most valuable goods owned by the household, including domestic, transport, and productive assets, were used in an adapted version of the household domestic asset index of Njuki et al. (2011). Livestock owned was left out and dealt with in a separate indicator (below). No age adjustment of assets was used and only the three most valuable assets were asked for for reasons of simplicity. Weights (Table 7) of the three most valuable assets were summed and assigned an indicator score according to Table 8.

Table 7. Assets and their weights as adopted from Njuki et al. (2011).

Asset	Weight	Asset	Weight
Domestic assets		*Transport assets*	
Cell phone	3	Bicycle	6
Chairs	1	Motorbike	48
Sofa set	3	Car	160
Cooking materials	1		
Radio	2	*Productive assets*	
Television	4	Mill	10
Fridge	4	Wheelbarrow	3
Solar light set	3	Ox plough	4
Plastic water tank	4	Laptop	10

Table 8. The sum of weights of the three most valueble goods and the subsequent indicator scores.

Sum of weights	Score
0-5	0
6-10	2
11-20	4
21-50	6
51-100	8
>101	10

Livestock

The livestock indicator was calculated based on the number of different livestock owned by the household and summed per household using tropical livestock units (TLU). TLU was values were based on Njuki et al. (2011) and can be found in Table 9. The indicator score was expressed in TLU with a maximum of 10 (having more than 10 TLU also resulted in a score of 10) (Fig. 8).

Table 9. Conversion of livestock types into tropical livestock units (TLU) based on (Njuki et al. 2011).

Livestock type	Weight (kg)	TLU
Cow	250	1.0
Goat	25	0.2
Sheep	25	0.2
Poultry	3	0.04
Donkey	175	0.8
Pig	50	0.3

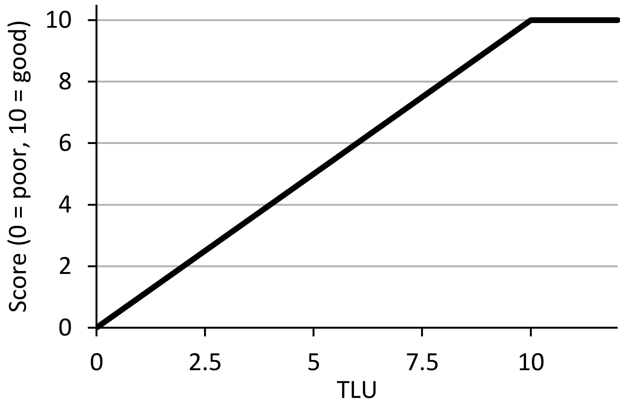


Fig. 8. Livestock indicator score as related to the number of tropical livestock units (TLU) owned by the household.

N input from N2 fixation

The N input from N_2-fixation indicator estimates the contribution of N_2-fixation to a desired minimum N input at farm scale. Total N inputs from N_2 fixation (kg) on farm level are calculated based on farmer estimated legume yields and literature values for the harvest index, N content in grain and stover and the percentage N_2 fixed by the specific legumes (Table 10). Total N inputs from N_2 fixation is than divided by the cultivated area (ha) to derive N inputs from N_2 fixation on farm level per ha. For this indicator an upper boundary (resulting in a score of 10) is set at 50 kg N ha^{-1}, which is equal to the minimum N input use as agreed in the Abudja declaration (African Union 2006) but might still be too low if production has to increase above 2000 kg ha^{-1} for maize for instance. This indicator therefore reflects the contribution of N_2-fixation to minimum N input levels on farm level.

Table 10. Crop specific dry matter (DM) contents, harvest indices, N content for grain and stover, and N_2-fixed for legumes

	DM content[1] (%)	Harvest index[1] (-)	N content grain[2] (%)	N content stover[2] (%)	N_2 fixed[3] (%)
Bush bean	90	0.40	5.3	1.4	50
Cowpea	89	0.40	5.1	1.3	70
Green gram	90	0.38	4.7	1.4	90
Groundnut	94	0.33	4.7	1.8	80
Maize	87	0.40	1.6	0.7	
Millet	90	0.27	1.8	0.6	
Rice	84	0.48	1.4	0.5	
Sorghum	87	0.26	1.7	0.7	
Soyabean	90	0.33	8.1	0.7	50/80[4]

[1] Data base Joost Wolf, personal communication December 2015; [2] 1.75×minimum N contents from Nijhof (1987), methodology Joost Wolf, personal communication; [3] Based on Giller (2001); [4] N_2 fixed for non-inoculated/inoculated soyabean (Giller 2001).

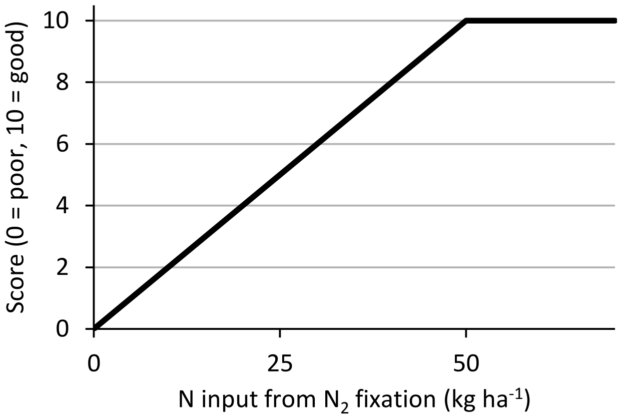


Fig. 9. N input from N_2 fixation indicator score as related to the N inputs from N_2 fixation at farm level.

Agro-diversity

The agro-diversity index relates the relative proportion of all different crops cultivated on the farm to risk reduction – if more crops are cultivated instead of only one or few crops, risks of for instance crop failure or price fluctuations are spread and therefore reduced. Simpsons diversity index (Simpson 1949), originally developed to asses species diversity, was adjusted into the following equation to calculate the agro-diversity index:

$$Agro - diversity\ index = 10 * \left(1 - \sum_{i=1}^{n} I_i^2\right)$$

Where I refers to the fraction of the total cultivated land designated to crop i and n revers to the number of crops cultivated on the farm. The agro-diversity index results in values between 0 and 10, where 0 means a very low diversity of crops and 10 means a very high diversity.

Price and yield variability

The respondent was asked to name their most important crops. For each of these crops it was asked whether yields and prices were very variable, a little variable, or stable, which resulted in a score of 0, 5 and 10 respectively. The average score across these most important crops was calculated per household to calculate the price variability and yield variability indicator scores.

Share of women in labour

Legumes and other options for sustainable intensification might change the labour division between men and women. Legumes are for instance often a women's crop. Women often experience an unequal burden when it comes to domestic and agricultural labour activities within a household. The share of women in labour indicator therefore compares the labour input of men and women for most important grain crops in the household. Most important grain crops were mostly maize or maize intercropped with legumes (e.g. beans, cowpea, soyabean) and if present also included the sole cropped legumes. For each of the most important management activities per crop (e.g. land preparation, sowing, weeding, harvesting, threshing) it was asked who had been doing it in the previous season (men, women, children, labourers, shared labour) and how long it took (working days). For this indicator the share of labour done by women in the household was compared with the share of labour done by men. To represent the unequal burden women often already take in domestic activities, an unequal scale was used in which 75% of labour or more done by women resulted in a score of 0 (Fig. 10).

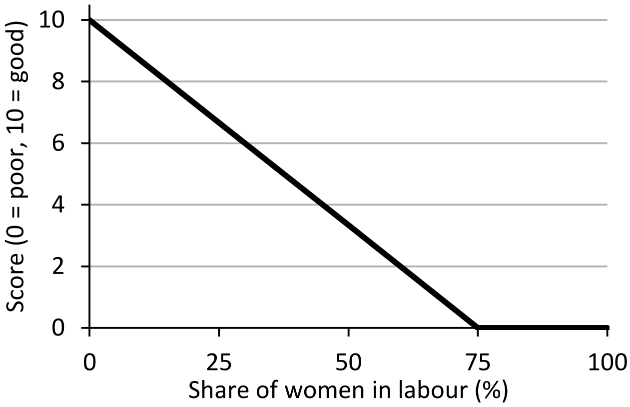


Fig. 10. Score as related to the share of women in labour of most important grain crops.

Women empowerment

The women of the household was asked whether it was her, the husband, or the two of them together to decide on farm management. This methodology was inspired by the inspired by the women empowerment in agriculture index as developed by Alkire et al. (2013). In total ten farm management decisions (e.g. which input are bought, what is sold of the crop yield, what animals are sold, what crops are planted) evaluated. A score per management decision of one was given if the women decided, a score of 0.5 if they decided together and a score of 0 if it was the husband to decide. The sum of the scores for this ten management decisions resulted in the women empowerment index.

Food security

The household food security indicator was based on the Months of Adequate Household Food Provisioning (MAHFP) indicator as developed by Swindale and Bilinsky (2010). In a first question it was asked whether in an average year there are months in the year in which (some) household member eat less because of food shortage. If this is the case it is asked to indicate which months of the year the household experiences food shortages. Based on the number of months in the year that the household experiences food insecurity, the household food security indicator score is calculated as follows:

$$\text{Food security indicator} = 10 \times \frac{(12 - \text{months with food shortage})}{12}$$

Post-harvest storage
Reducing post-harvest losses are an important factor that could increase food availability in SSA. Several options for improved post-harvest practices were available in both research sites. A score was given according to the impact a management option could have on reducing losses. Improved storage methods that could be used within the homestead were given a higher weight than centralized or communal storage as measures within the homestead can have a direct impact on food security of a household (Table 11). Both triple layered bags (or high density polyethylene) and storage protection chemicals can have strong impact on reducing pest damage (De Groote et al. 2013). Knowing the name of a storage protection chemicals was used as an indicator for appropriate use (similar as used for the indicator for crop protection use).

Table 11. Scoring of improved post-harvest practices.

Post-harvest protection method	Score	
	Yes	No
Improved storage method (e.g. triple layered bags)	3.5	0
Uses storage protection chemical	3.5	0
Knows name of storage protection chemical (e.g. Actellic)	1	0
Centralized storage available within the community	1	0
Uses centralized storage	1	0

Market access
Good market access is important for buying inputs and selling surplus and therefore is a key enabling factor for (sustainable) intensification. Farmers' reported traveling time to reach the market (in which farming households can buy inputs and sell surplus) was used as an indicator for market access. Traveling time represents both road access/quality and the type of transport that a farmer is able to afford (e.g. some are able to afford a motor bike taxi while others have to walk). A maximum time resulting in a score of 0 was at 120 minutes (one way).

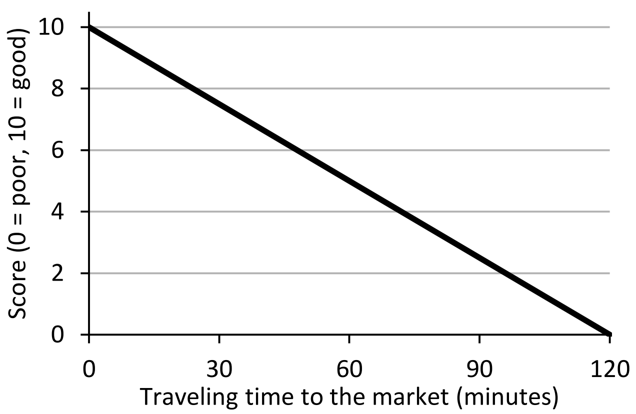


Fig. 11. Market access score as related to farmers' repported traveling time (one way) to the market in which a farming household is able to buy inputs and sell surplus.

Frequency of extension services

Good extensions services are key for sustainable intensification of smallholder farming systems in SSA. For this indicator no distinction was made between extension services of governmental and none governmental extension services. The frequency of extension services indicator was based on the question: what was the last time that you met with an extension agent, joint in an extension activity (e.g. field day), or received any other extension service? A score was given based on the time that had elapsed since the last extension activity and the time of the survey (Table 12).

Table 12. Frequency of extension services indicator scores. The difference between weekly and last week is that some farmers received regular extension services (weekly), while others received it last week, but not on a regular basis.

Last time extension services?	Score
Weekly	10
Last week	8
Last month	6
<6 months	4
<1 year	2
>1 year	1
Not/do not know	0

Crop protection use

The key concern of crop protection use by smallholder farmers might proper and careful use. A case study executed by CropLife for N2Africa in Borno state, Nigeria revealed that 50% of the participants had difficulties reading the label of crop protection agent containers and 65% mentioned a lack of knowledge on which crop protection agents to buy (CropLife 2015). If smallholder farmers use crop protection agents, knowing the name of the applied crop protection agent and using some simple safety measures might therefore be a first step towards save and judicious use of crop protection agents.

Three questions on proper management of crop protection agents were asked if crop protection agents were used in a field in the previous season; what is the name of the crop protection agent, was (simple) protective clotting (mouth cover, boots, goggles) used, and how is it stored? A crop protection indicator score of 10 was given if no crop protection agents were used. 2.5 points were given for a satisfactory answer on each of three management questions, resulting in a highest score of 7.5 if crop protection agents were used safely.

N surplus

N surplus (N input – N output) was calculated using the following formula.

$$N\ surplus = (N\ in\ grain + N\ in\ stover\ out\ of\ field) - (N\ mineral\ fertilizer + N\ manure + N_2\ fixed)$$

N inputs and outputs were estimated using farmers' reported values for grain yield per field, stover use (left in the field, taken out of the field), mineral fertilizer application, and manure application and values from literature for harvest index, dry matter content, N-contents, and N_2 fixation for legumes (Table 10). Manure application was reported in local units and converted to kilogram. Manure dry matter content was estimated to be 55 % and the N content at application 1.04% (based on data from western Kenya, Tittonell et al. (2008)).

Table 13. Weight (measured) of local units of manure.

Local unit	Weight (kg)
Bucket	15
Bag	50
Wheelbarrow	70
Donkey cart	154

All values were calculated to a per hectare bases to calculate the N surplus per field in kg N ha^{-1}. A weighted average (based on field size) was used to calculate the farm level N surplus (kg N ha^{-1}) for all fields cultivated with grain crops. The 'traffic light' indicator scheme as proposed by the EU Nitrogen Expert Panel (2015) (Table 14) was modified to be used as N surplus indicator (Fig. 12).

Table 14. Traffic light indicator scheme for N surplus of cropping systems (EU Nitrogen Expert Panel 2015)

Interpretation	N surplus
Very high	>120
High	80-120
Modest	50-80
Low	20-50
Very low	<20

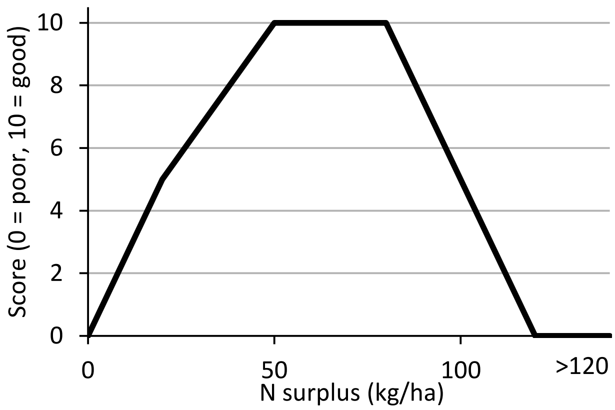


Fig. 12. N surplus indicator score as related to N surplus (kg ha^{-1}), based on the traffic light indicators scheme of the EU Nitrogen Expert Panel (2015).

Nitrogen use efficiency

Nitrogen use efficiency (NUE) for all fields containing grain crops in the previous season was calculated as:

$$NUE_{field} = \frac{(N\ in\ grain + N\ in\ stover\ out\ of\ field)}{(N\ mineral\ fertilizer + N\ manure + N_2\ fixed)}$$

NUE at farm level was calculated using a weighted (based on field size) average across all fields for which the NUE was calculated. The ‘traffic light indicator’ scheme for nitrogen use efficiency as developed by Brentrup and Palliere (2010) and the EU Nitrogen Expert Panel (2015) (Table 15) was adopted to be used as NUE indicator (Fig. 13).

Table 15. Traffic light indicator scheme for nitrogen use efficiency of cropping systems (Brentrup and Palliere 2010; EU Nitrogen Expert Panel 2015)

Interpretation	Nitrogen use efficiency (NUE) (%)
Soil N mining	>100
Risk of soil N mining	90-100
Balanced N fertilization	70-90
Risk of N losses	50-70
High risk of N losses	<50

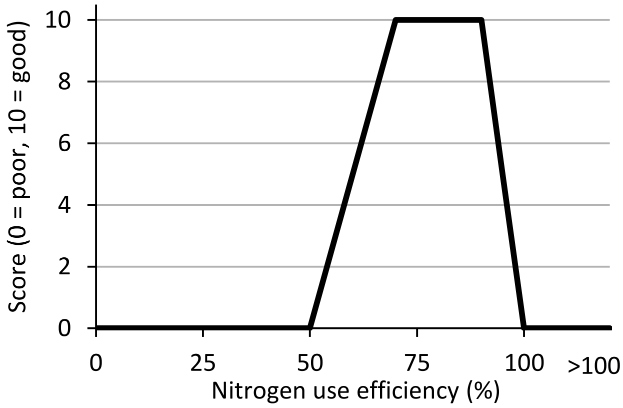


Fig. 13. Nitrogen use efficiency score for different nitrogen use efficiencies.

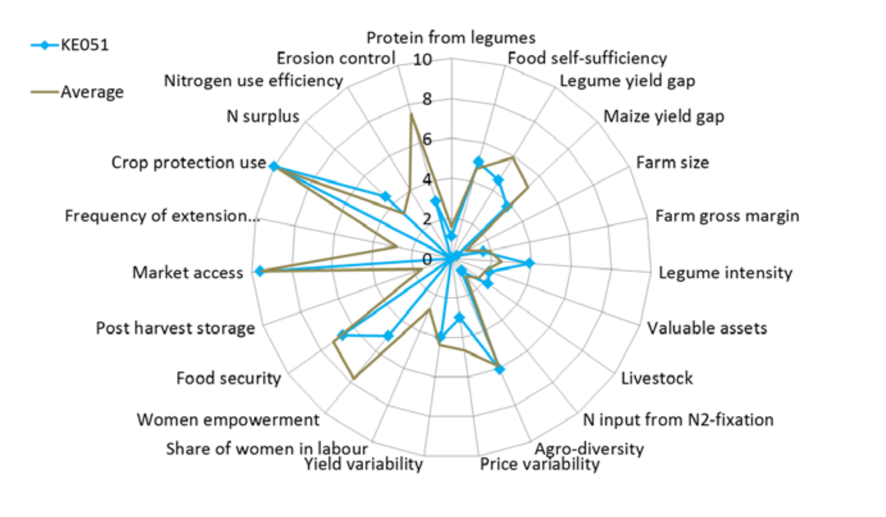
Erosion control

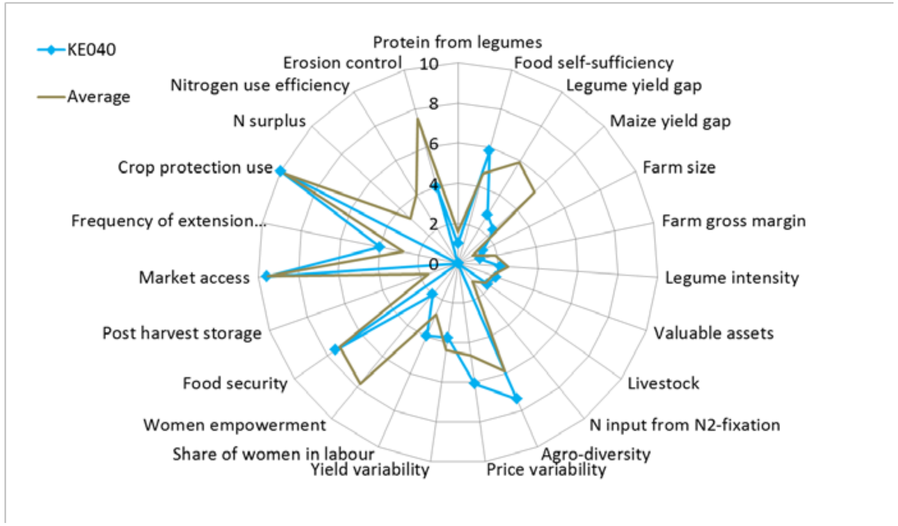
Slope (flat, steep, very steep), visible erosion (none, moderate, severe), and measures against erosion (e.g. Napier grass strips, tree bunds, residues bunds, ploughing along the contour) were assessed per field. A field was scored 10 if no erosion was observed and fields were classified as flat. If a field was either steep or very steep or if moderate or severe erosion was observed it received a score of 0 if no measures against erosion were taken and a score of 5 if measures against erosion were taken. A weighted average, using the relative contribution of the size of a field to the total farm size, across all cultivated fields was used to calculated the erosion control index at farm scale.

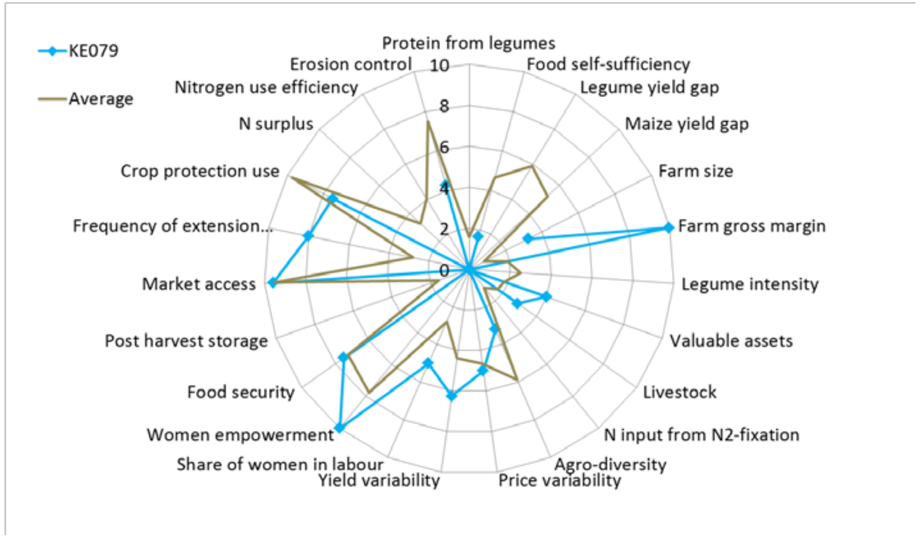
Annex III – Results of spider web indicators per household, West Kenya

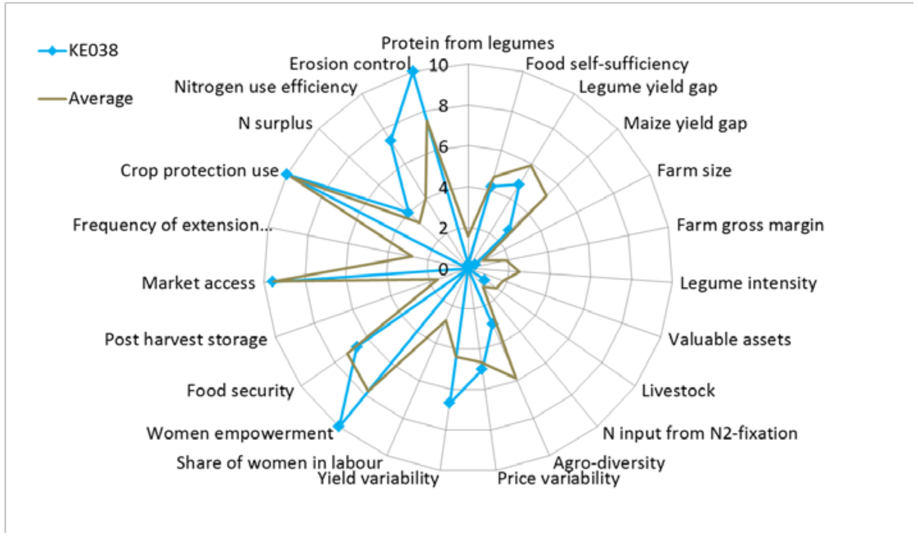
- Households are ordered according to their overall sustainability score (average across principles).
- The grey, average line is the average outcome across all households per research site.
- In Migori three additional households were sampled in the field to add soyabean cultivating households.

Vihiga

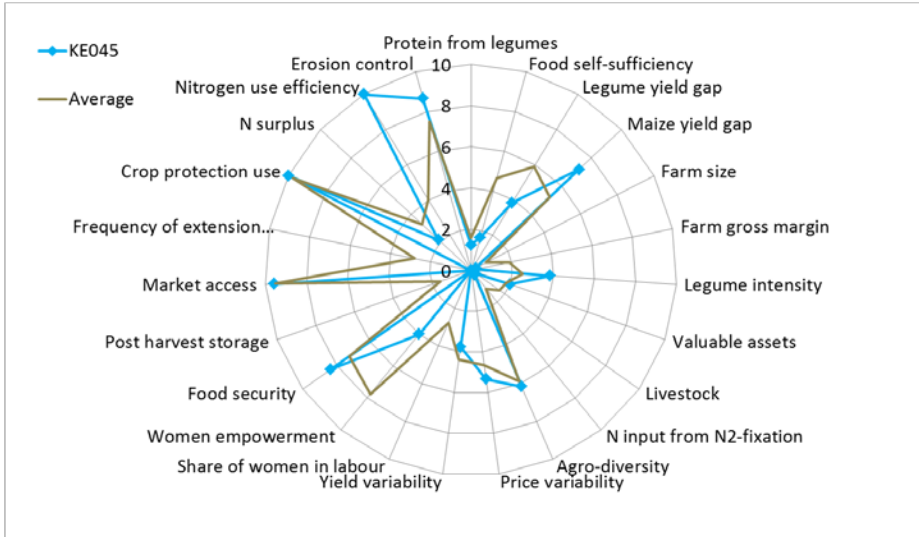








*Average is the average across households per research site, Vihiga in this case.


KE045
Average
Protein from legumes
Food self-sufficiency
Legume yield gap
Maize yield gap
Farm size
Farm gross margin
Legume intensity
Valuable assets
Livestock
N input from N2-fixation
Agro-diversity
Price variability
Yield variability
Share of women in labour
Women empowerment
Food security
Post harvest storage
Market access
Frequency of extension...
Crop protection use
N surplus
Nitrogen use efficiency
Erosion control
10
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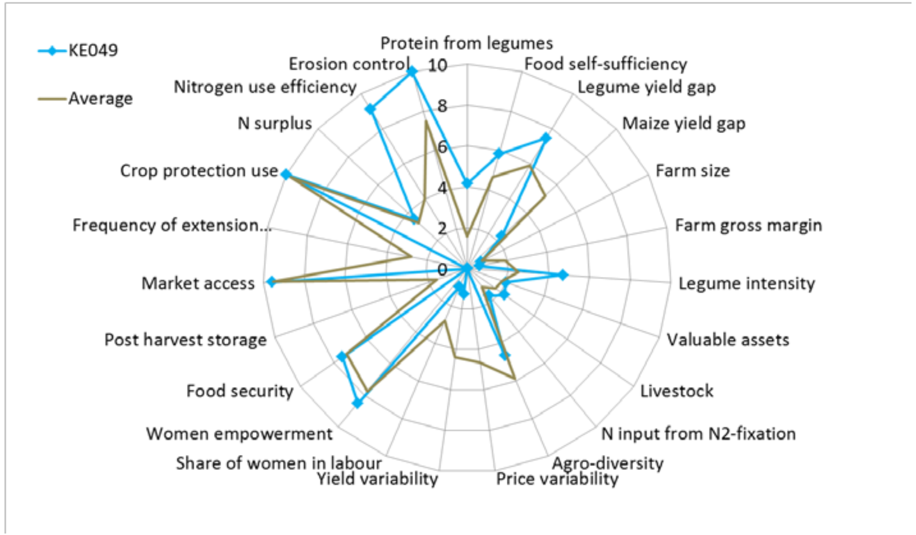
KE049
Average
Protein from legumes
Food self-sufficiency
Legume yield gap
Maize yield gap
Farm size
Farm gross margin
Legume intensity
Valuable assets
Livestock
N input from N2-fixation
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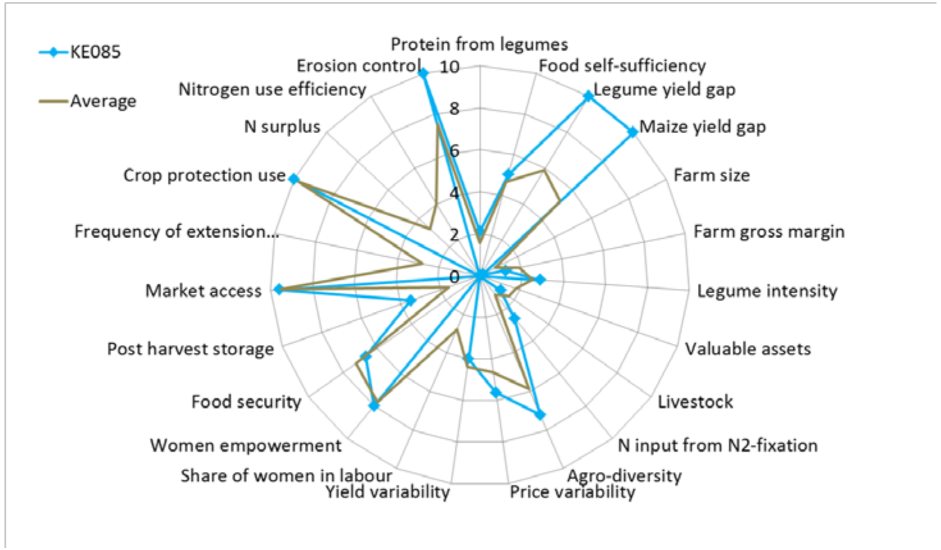
KE085
Average
Protein from legumes
Food self-sufficiency
Legume yield gap
Maize yield gap
Farm size
Farm gross margin
Legume intensity
Valuable assets
Livestock
N input from N2-fixation
Agro-diversity
Price variability
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Frequency of extension...
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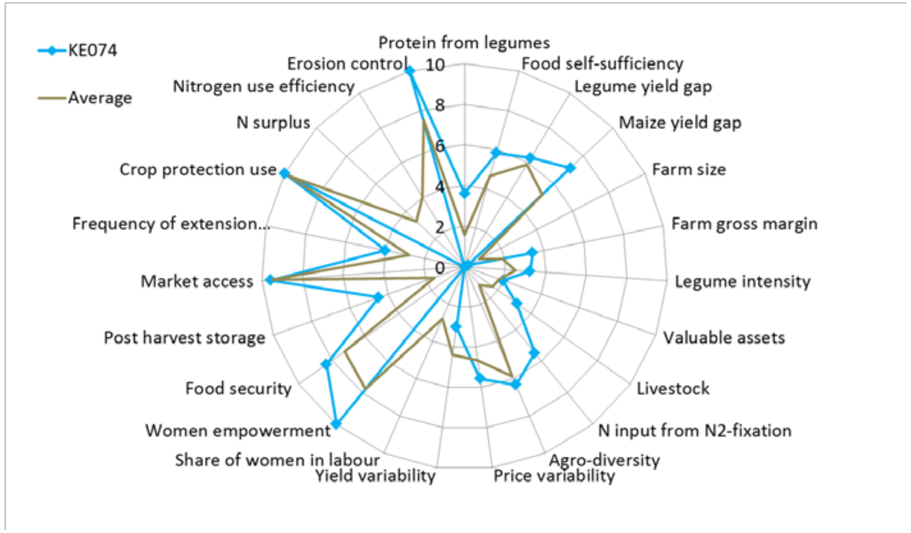
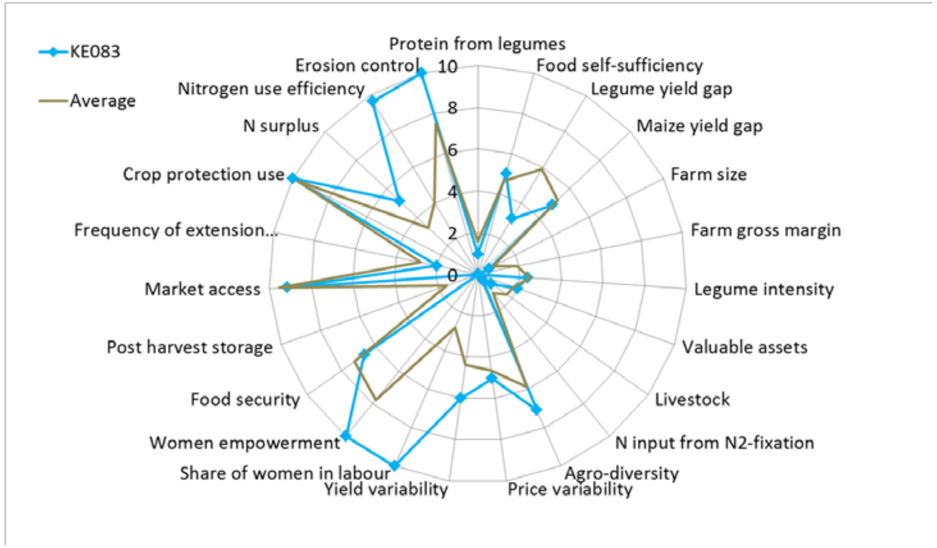
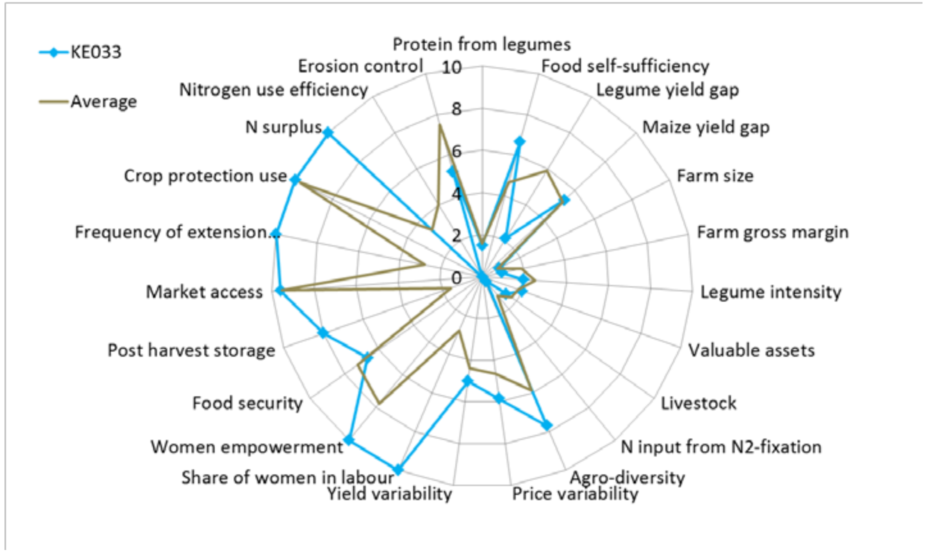
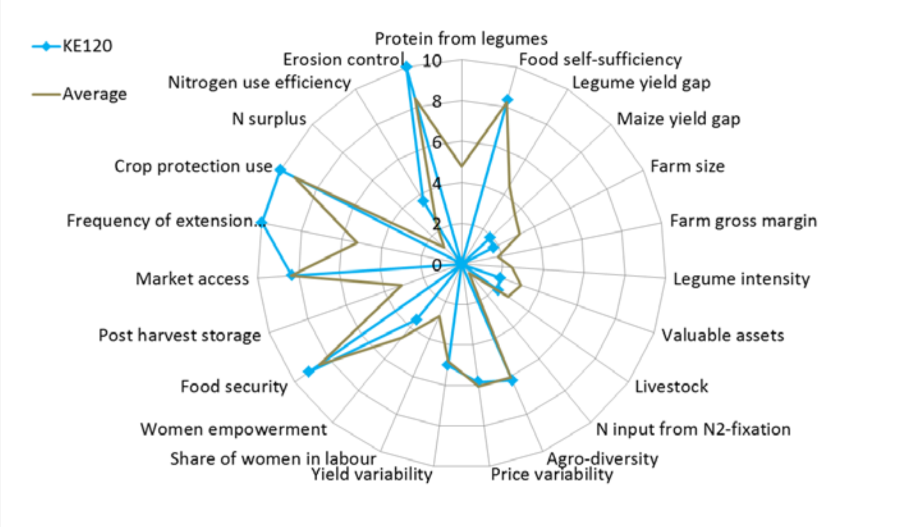
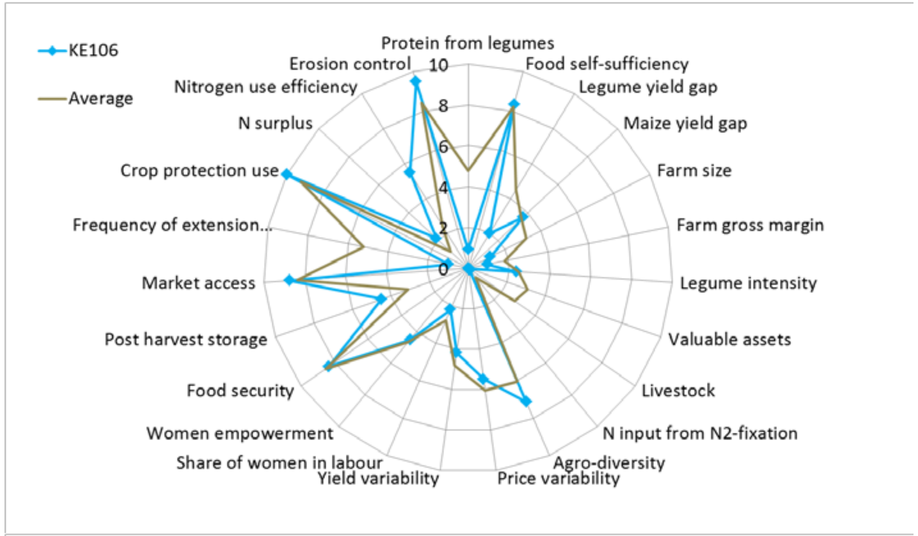

KE074
Average
Protein from legumes
Food self-sufficiency
Legume yield gap
Maize yield gap
Farm size
Farm gross margin
Legume intensity
Valuable assets
Livestock
N input from N2-fixation
Agro-diversity
Price variability
Yield variability
Share of women in labour
Women empowerment
Food security
Post harvest storage
Market access
Frequency of extension...
Crop protection use
N surplus
Nitrogen use efficiency
Erosion control
10
8
6
4
2
0

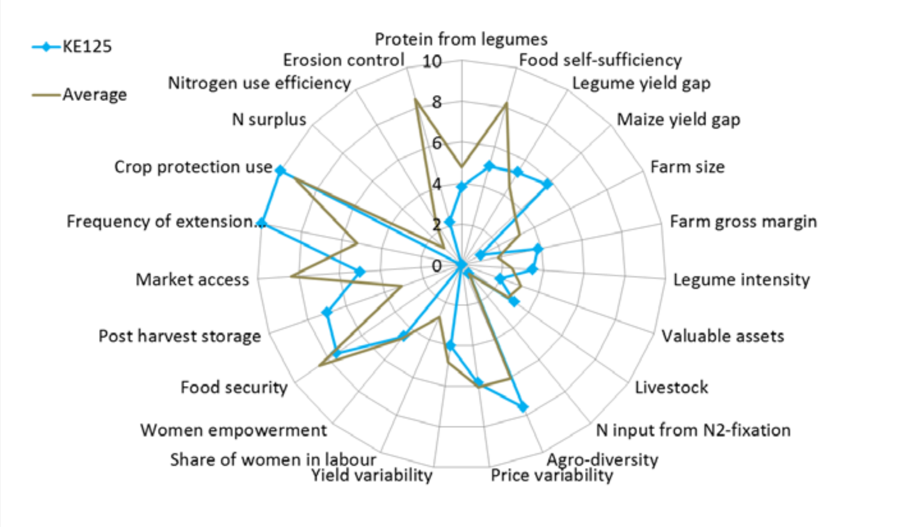

KE083
Average
Protein from legumes
Food self-sufficiency
Legume yield gap
Maize yield gap
Farm size
Farm gross margin
Legume intensity
Valuable assets
Livestock
N input from N2-fixation
Agro-diversity
Price variability
Yield variability
Share of women in labour
Women empowerment
Food security
Post harvest storage
Market access
Frequency of extension...
Crop protection use
N surplus
Nitrogen use efficiency
Erosion control
10
8
6
4
2
0

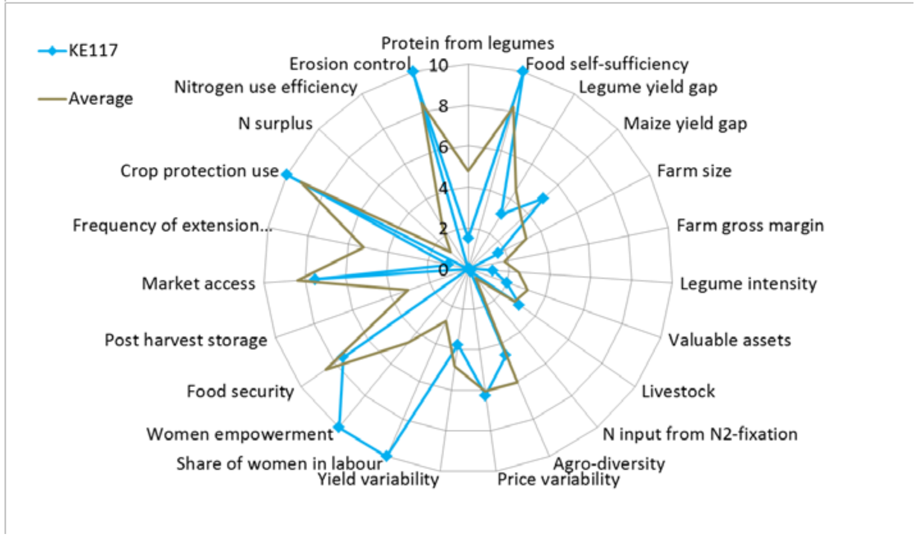

KE033
Average
Protein from legumes
Food self-sufficiency
Legume yield gap
Maize yield gap
Farm size
Farm gross margin
Legume intensity
Valuable assets
Livestock
N input from N2-fixation
Agro-diversity
Price variability
Yield variability
Share of women in labour
Women empowerment
Food security
Post harvest storage
Market access
Frequency of extension...
Crop protection use
N surplus
Nitrogen use efficiency
Erosion control
10
8
6
4
2
0

Migori

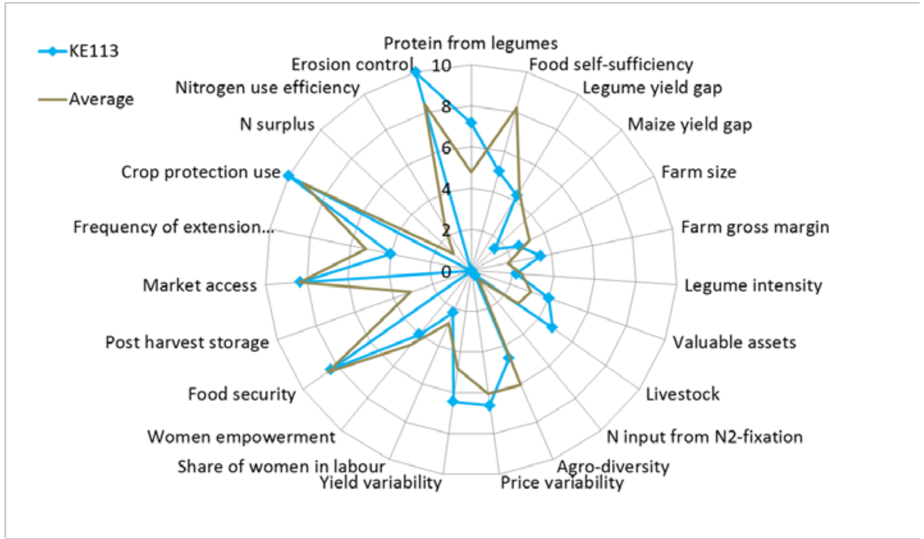


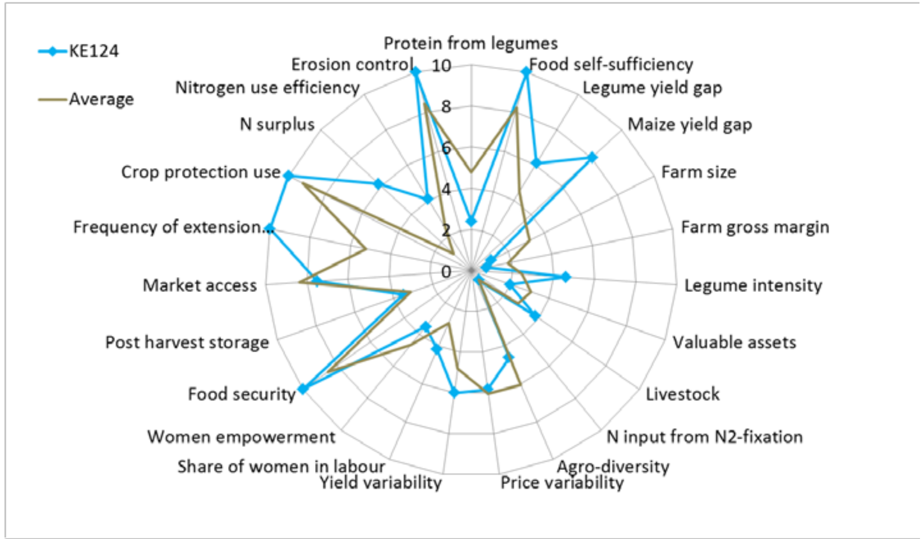


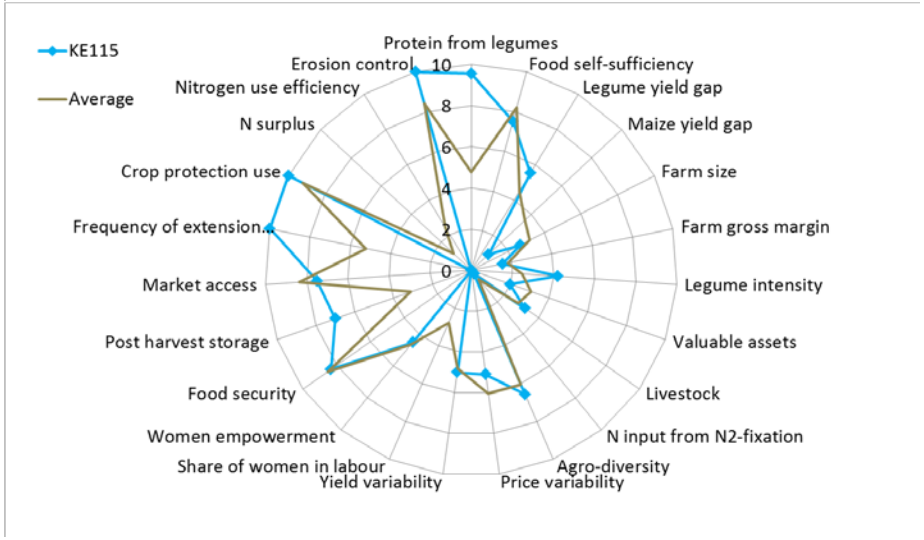


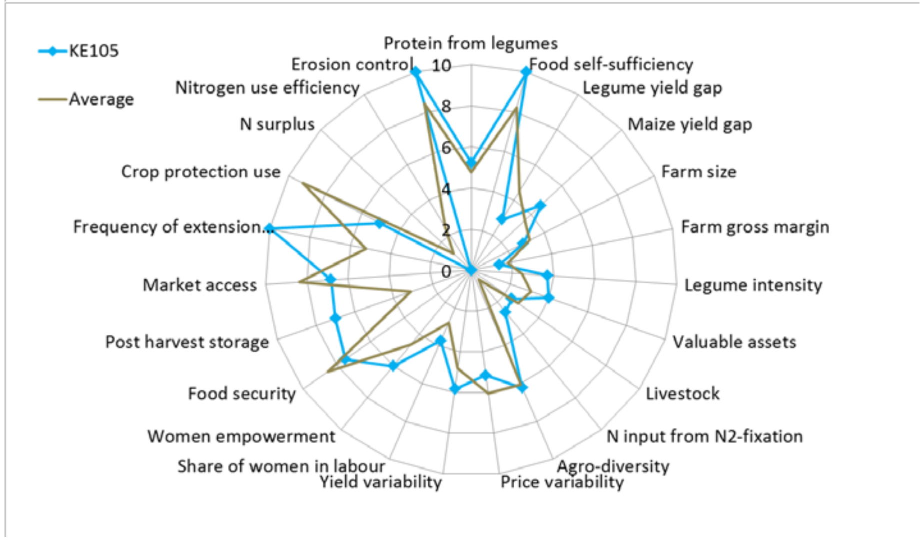


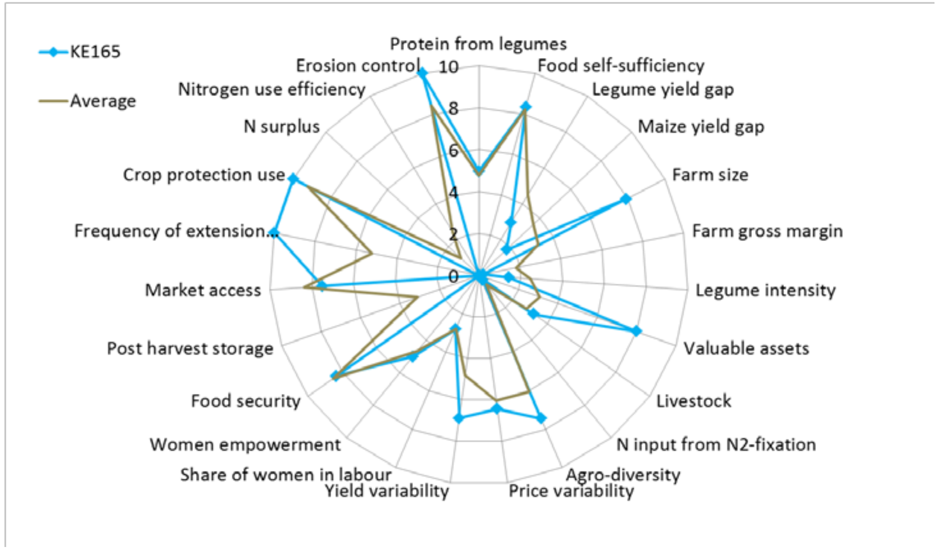
*Average is the average across households per research site, Migori in this case. Farm codes starting with KE_NEW were selected for cultivating soyabean.

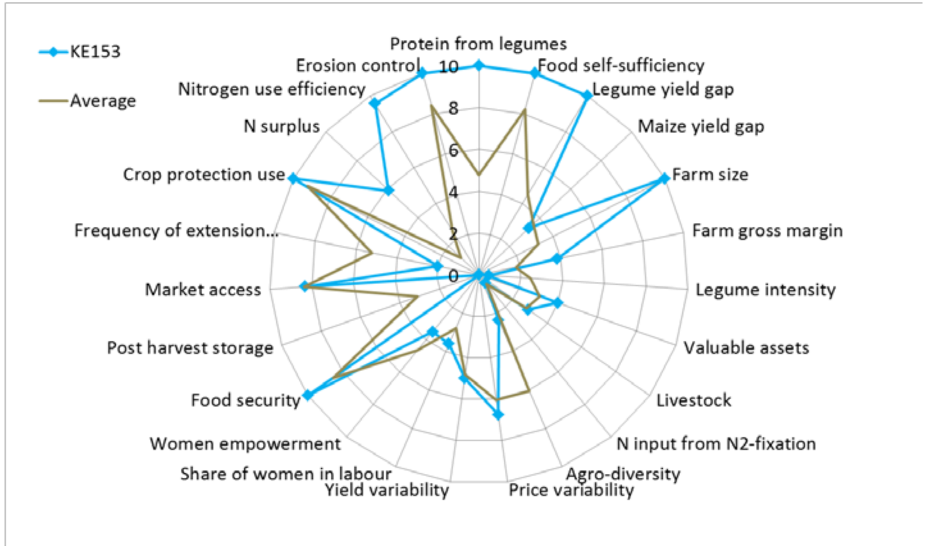

KE113
Average
Protein from legumes
Food self-sufficiency
Legume yield gap
Maize yield gap
Farm size
Farm gross margin
Legume intensity
Valuable assets
Livestock
N input from N2-fixation
Agro-diversity
Price variability
Yield variability
Share of women in labour
Women empowerment
Food security
Post harvest storage
Market access
Frequency of extension...
Crop protection use
N surplus
Nitrogen use efficiency
Erosion control
10
8
6
4
2
0


KE124
Average
Protein from legumes
Food self-sufficiency
Legume yield gap
Maize yield gap
Farm size
Farm gross margin
Legume intensity
Valuable assets
Livestock
N input from N2-fixation
Agro-diversity
Price variability
Yield variability
Share of women in labour
Women empowerment
Food security
Post harvest storage
Market access
Frequency of extension...
Crop protection use
N surplus
Nitrogen use efficiency
Erosion control
10
8
6
4
2
0

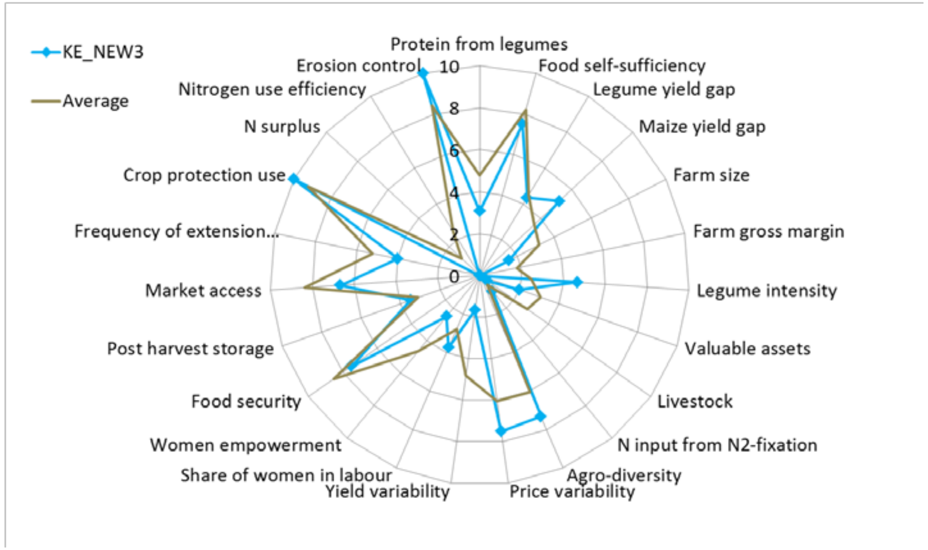

KE115
Average
Protein from legumes
Food self-sufficiency
Legume yield gap
Maize yield gap
Farm size
Farm gross margin
Legume intensity
Valuable assets
Livestock
N input from N2-fixation
Agro-diversity
Price variability
Yield variability
Share of women in labour
Women empowerment
Food security
Post harvest storage
Market access
Frequency of extension...
Crop protection use
N surplus
Nitrogen use efficiency
Erosion control
10
8
6
4
2
0

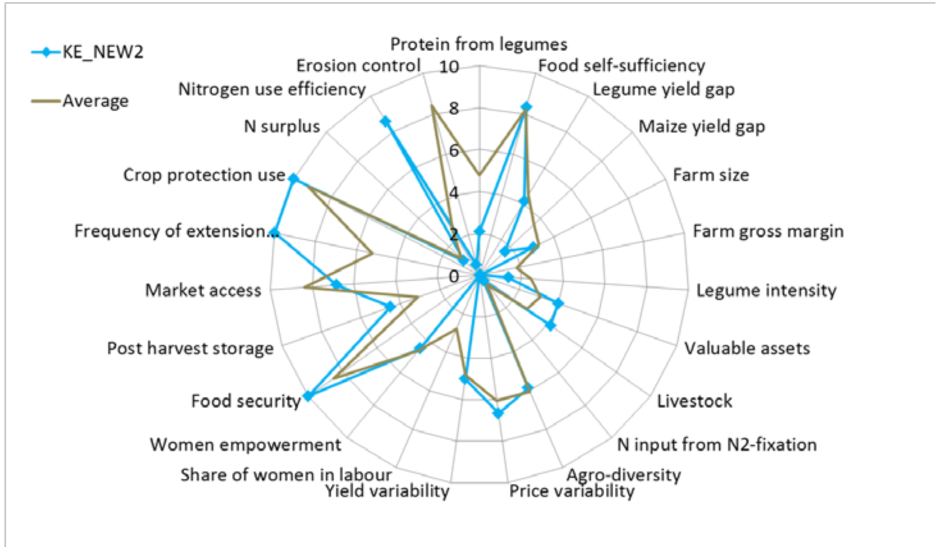

KE105
Average
Protein from legumes
Food self-sufficiency
Legume yield gap
Maize yield gap
Farm size
Farm gross margin
Legume intensity
Valuable assets
Livestock
N input from N2-fixation
Agro-diversity
Price variability
Yield variability
Share of women in labour
Women empowerment
Food security
Post harvest storage
Market access
Frequency of extension...
Crop protection use
N surplus
Nitrogen use efficiency
Erosion control
10
8
6
4
2
0

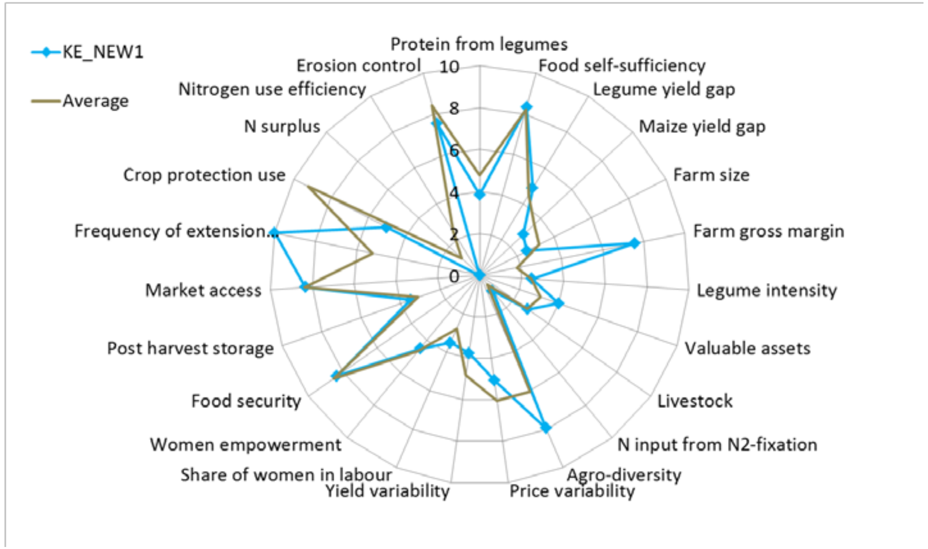

KE165
Average
Protein from legumes
Food self-sufficiency
Legume yield gap
Maize yield gap
Farm size
Farm gross margin
Legume intensity
Valuable assets
Livestock
N input from N2-fixation
Agro-diversity
Price variability
Yield variability
Share of women in labour
Women empowerment
Food security
Post harvest storage
Market access
Frequency of extension...
Crop protection use
N surplus
Nitrogen use efficiency
Erosion control
10
8
6
4
2
0


KE153
Average
Protein from legumes
Food self-sufficiency
Legume yield gap
Maize yield gap
Farm size
Farm gross margin
Legume intensity
Valuable assets
Livestock
N input from N2-fixation
Agro-diversity
Price variability
Yield variability
Share of women in labour
Women empowerment
Food security
Post harvest storage
Market access
Frequency of extension...
Crop protection use
N surplus
Nitrogen use efficiency
Erosion control
10
8
6
4
2
0

Migori (Households selected for cultivating soyabean)



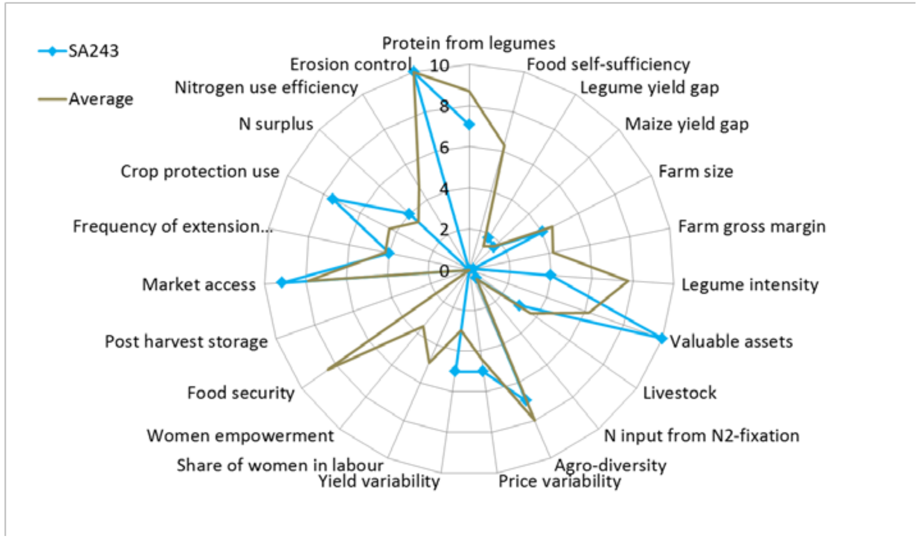


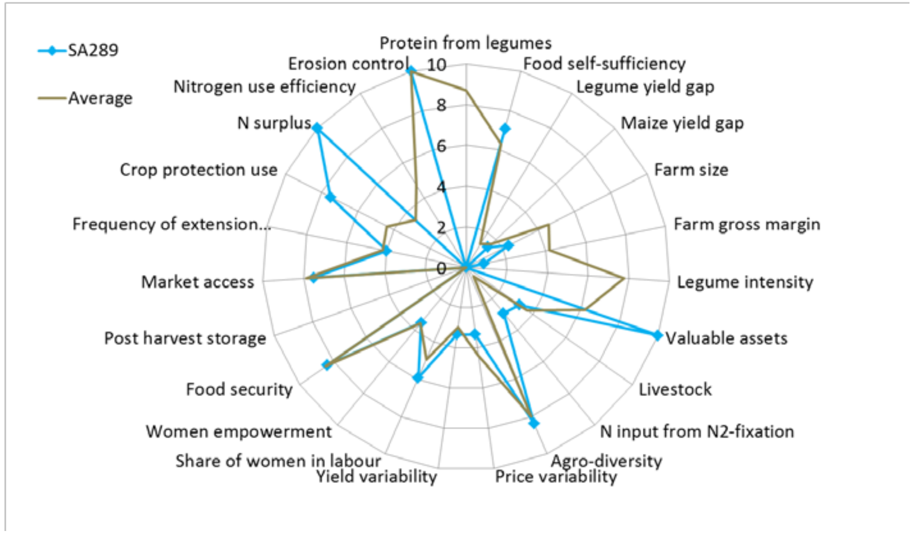


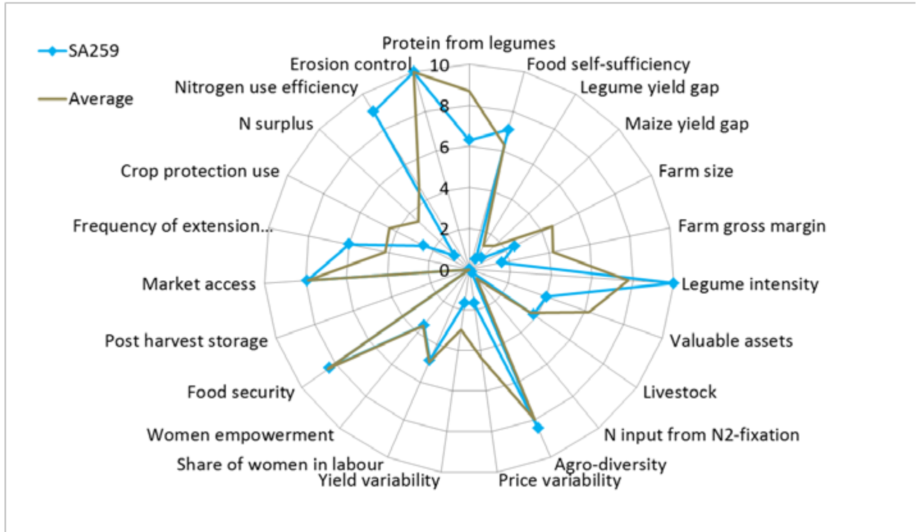
Annex IV – Results of spider web indicators per household, Northern Ghana

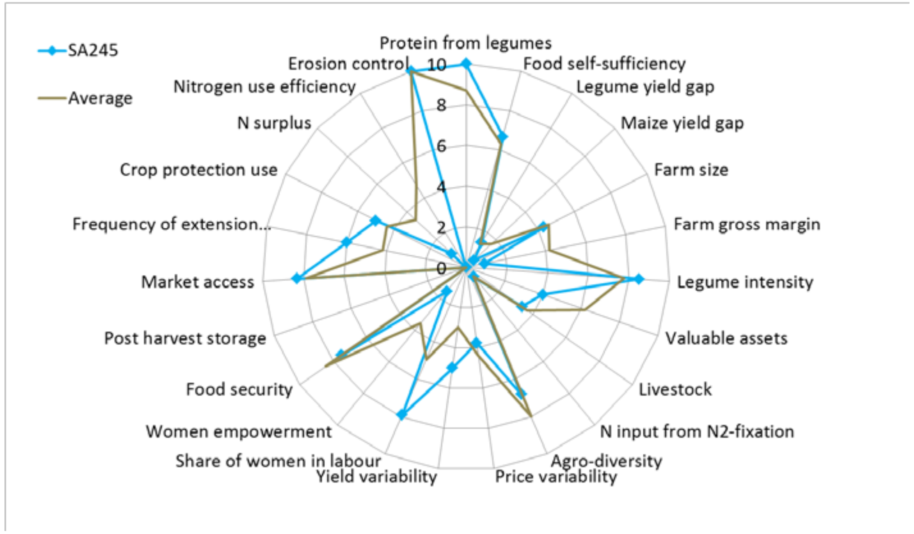
- Households are ordered according to their overall sustainability score (average across principles).
- The grey, average line is the average outcome across all households per research site.

Savelugu

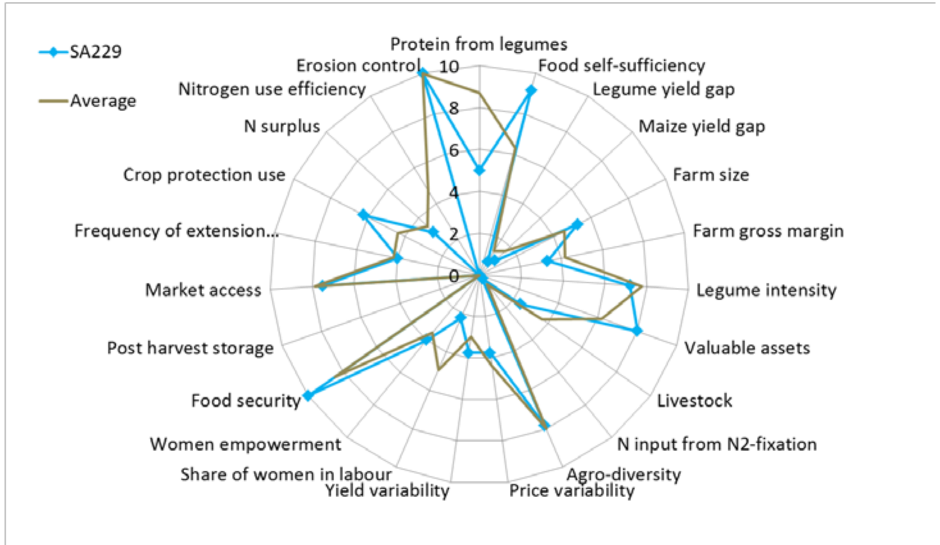


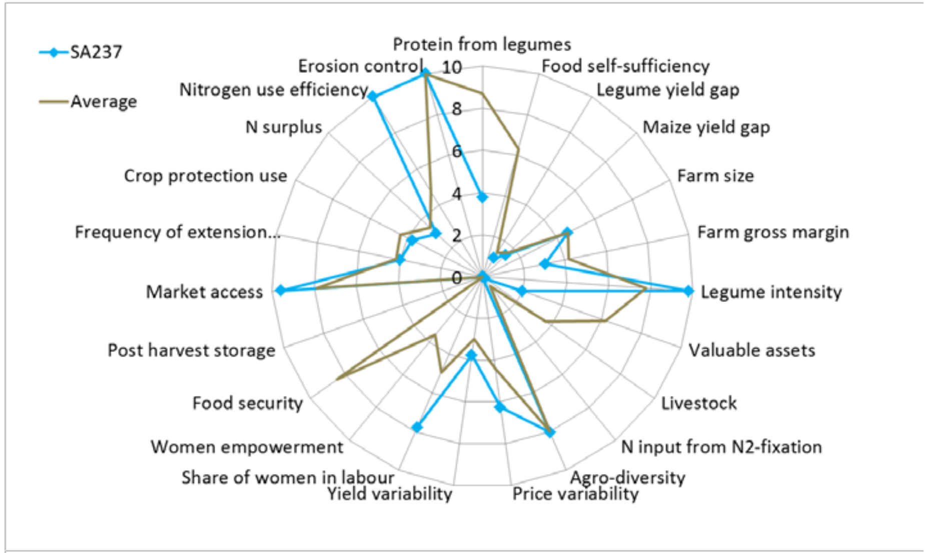


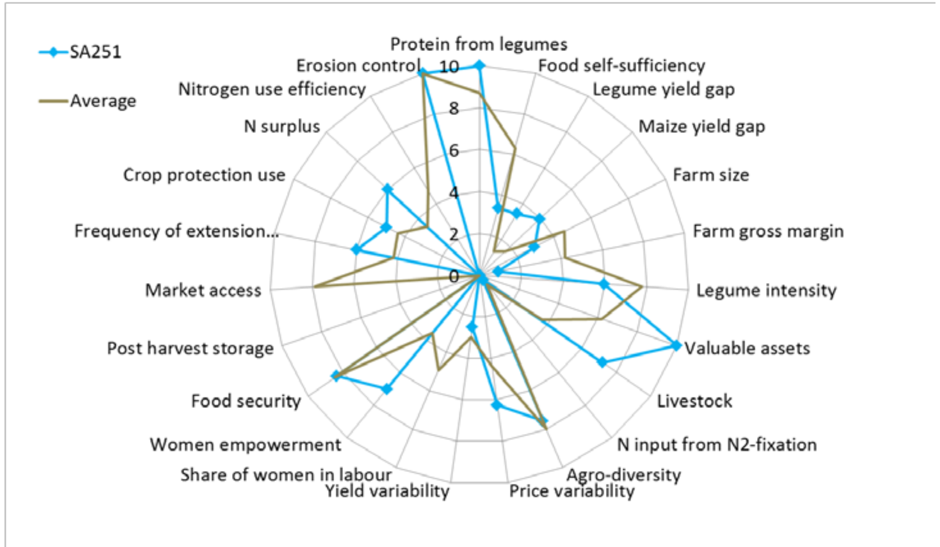


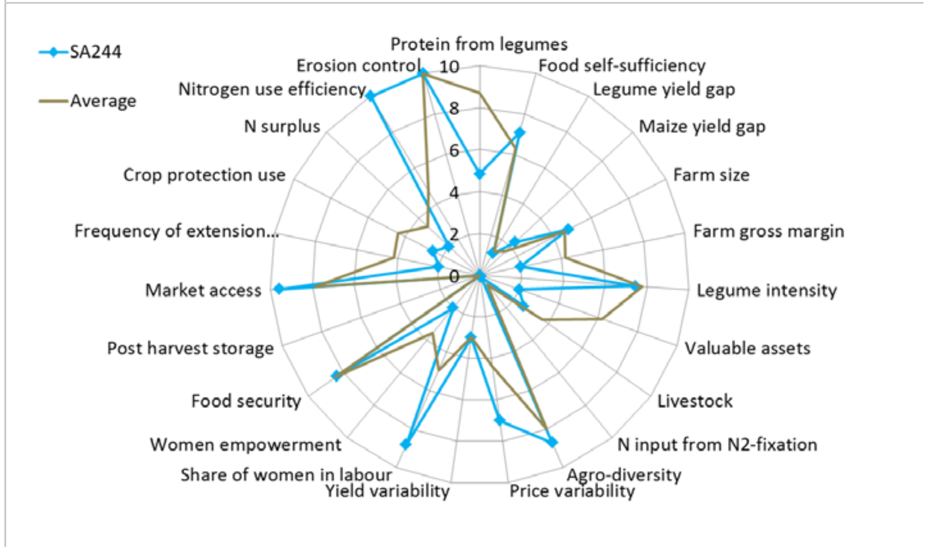


*Average is the average across households per research site, Savelugu in this case.

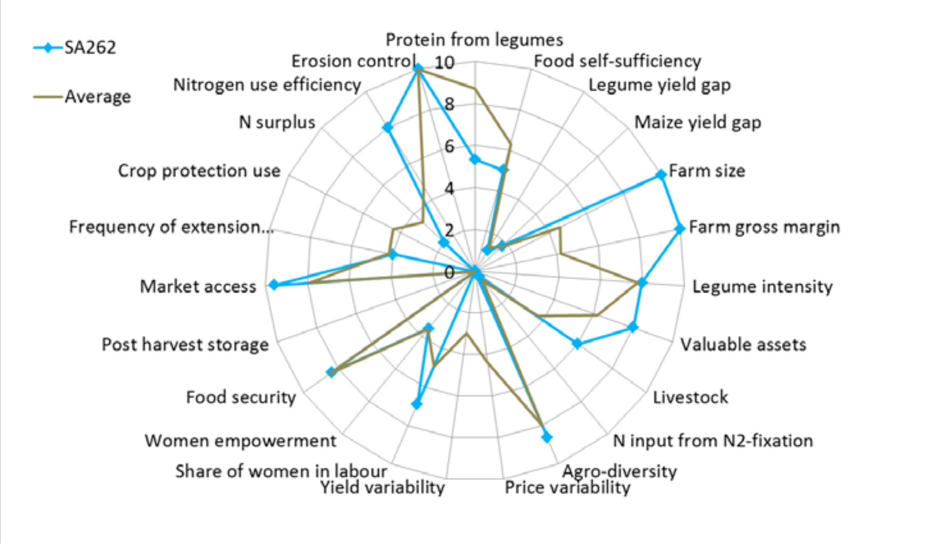


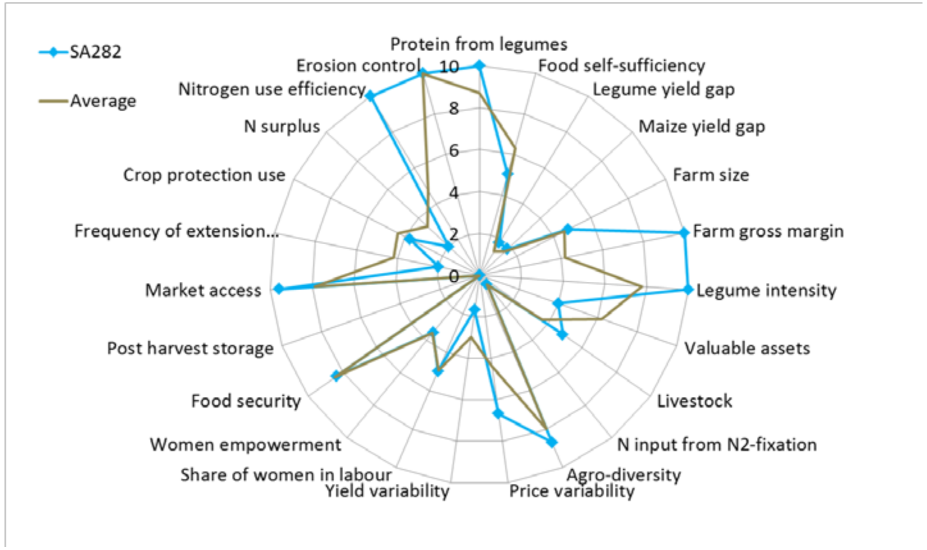




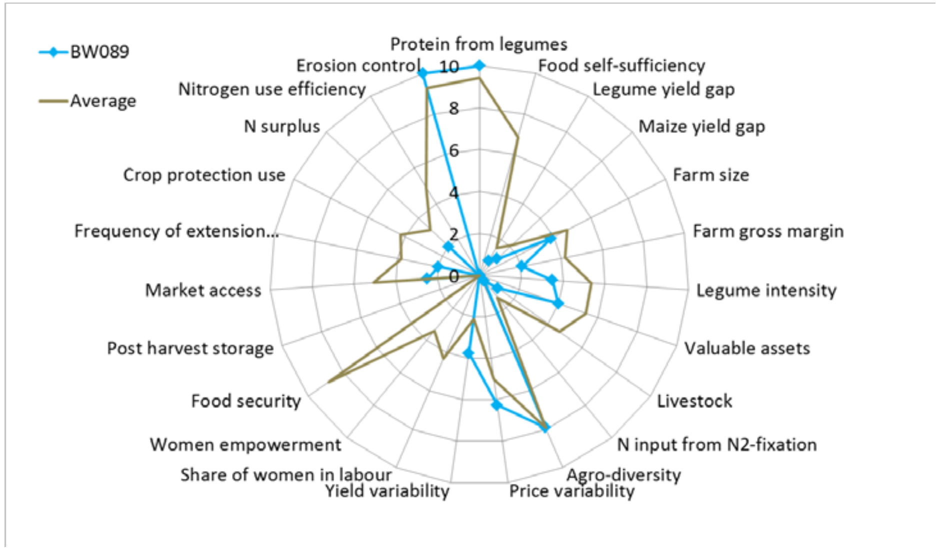


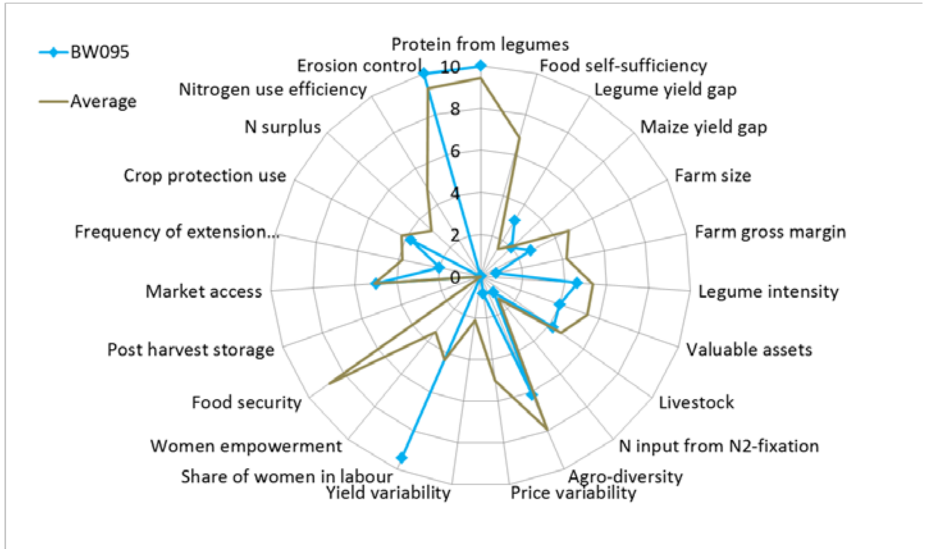
*Average is the average across households per research site, Savelugu in this case.

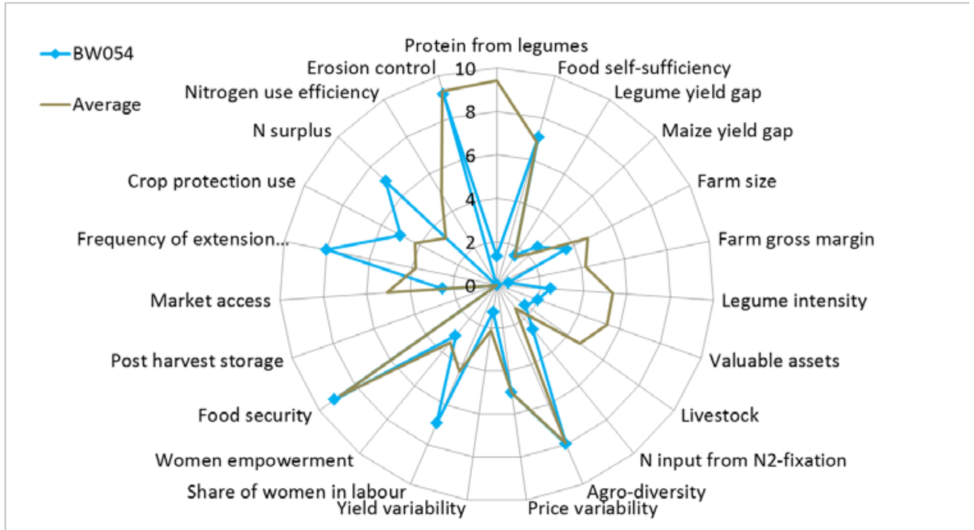

SA262
Average
Protein from legumes
Food self-sufficiency
Legume yield gap
Maize yield gap
Farm size
Farm gross margin
Legume intensity
Valuable assets
Livestock
N input from N2-fixation
Agro-diversity
Price variability
Yield variability
Share of women in labour
Women empowerment
Food security
Post harvest storage
Market access
Frequency of extension...
Crop protection use
N surplus
Nitrogen use efficiency
Erosion control
10
8
6
4
2
0

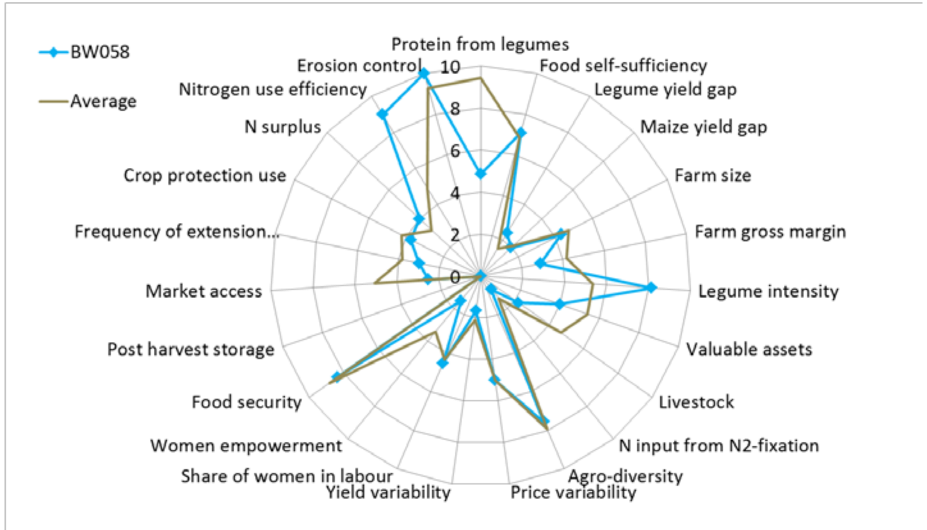

SA282
Average
Protein from legumes
Food self-sufficiency
Legume yield gap
Maize yield gap
Farm size
Farm gross margin
Legume intensity
Valuable assets
Livestock
N input from N2-fixation
Agro-diversity
Price variability
Yield variability
Share of women in labour
Women empowerment
Food security
Post harvest storage
Market access
Frequency of extension...
Crop protection use
N surplus
Nitrogen use efficiency
Erosion control
10
8
6
4
2
0

Bawku West

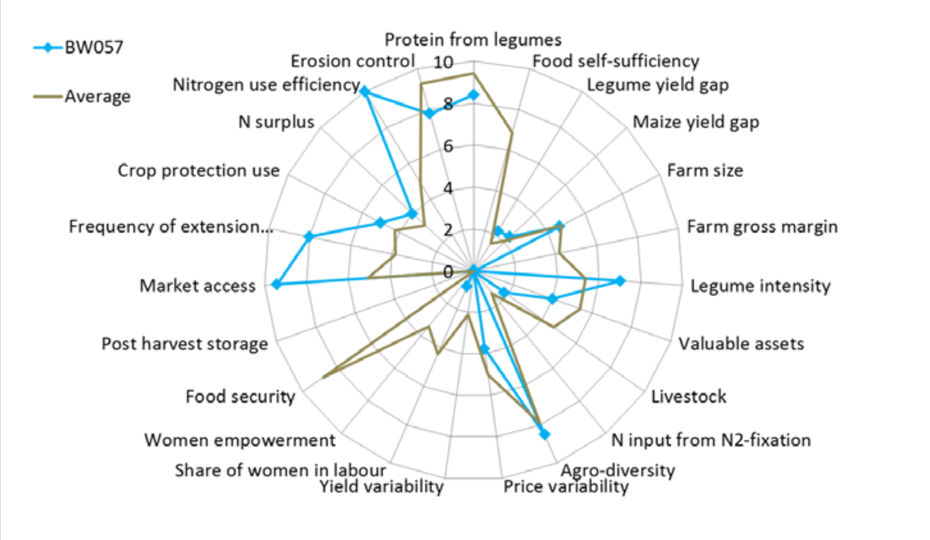


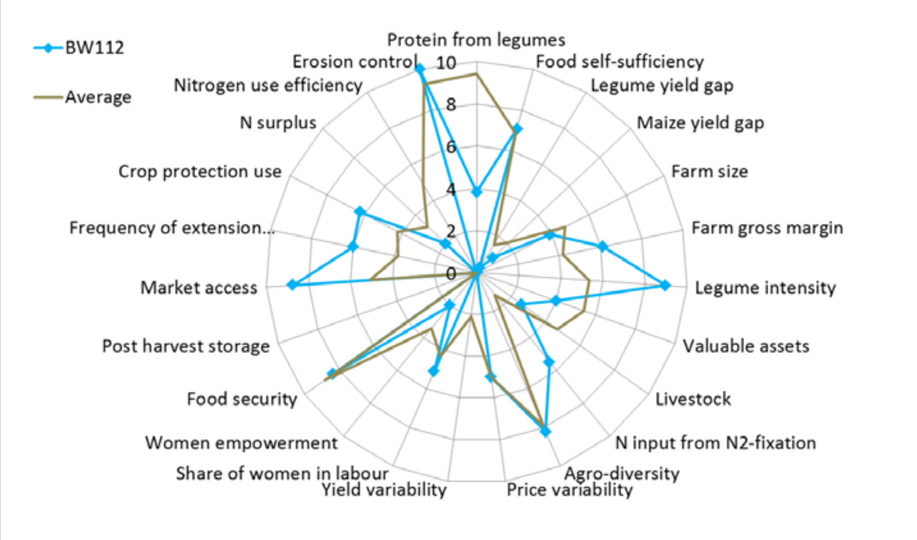


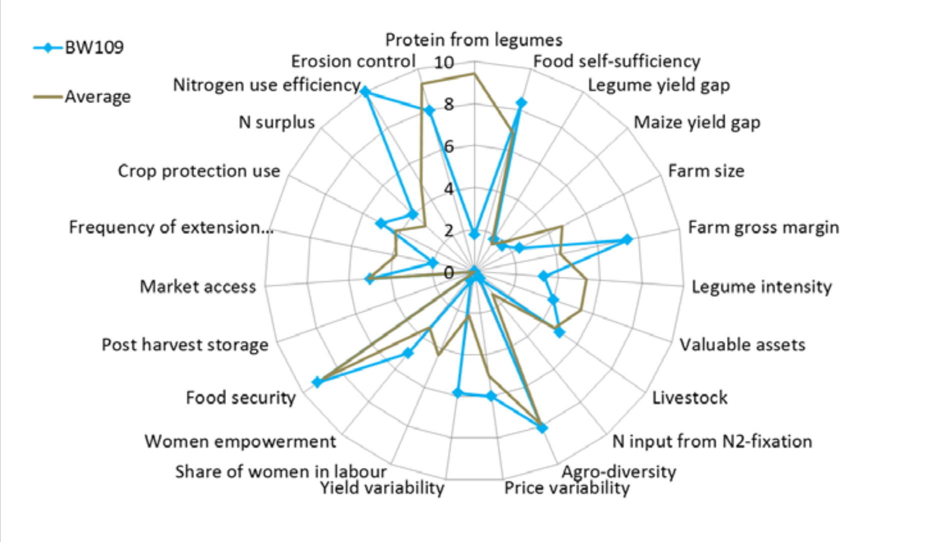


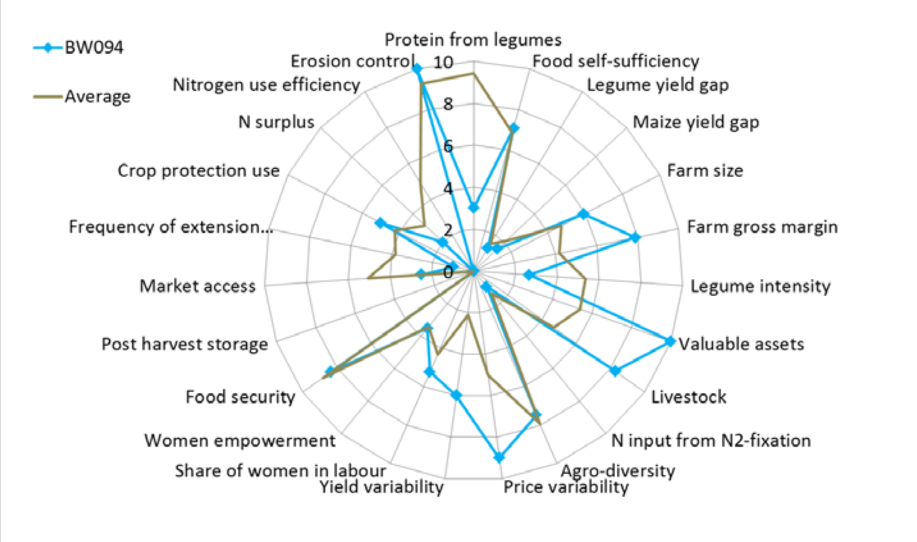


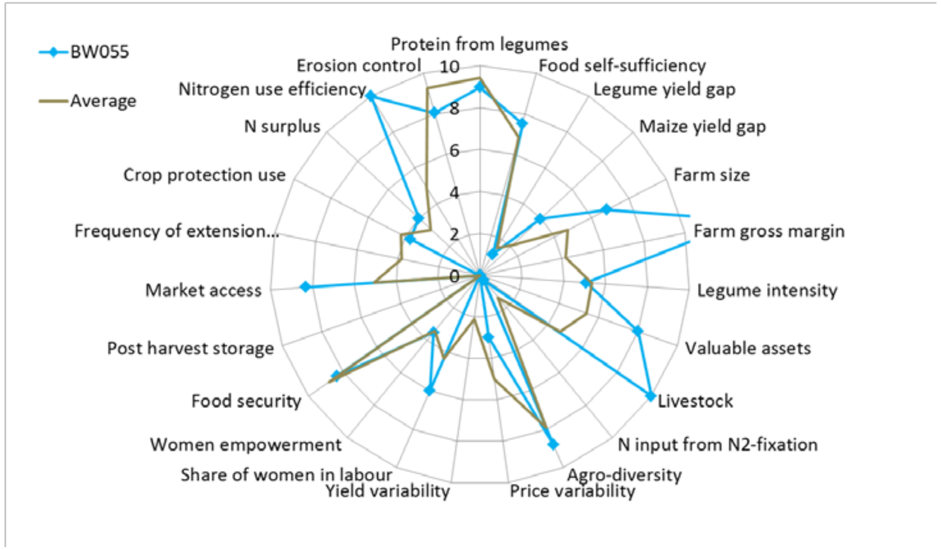
*Average is the average across households per research site, Bawku West in this case.

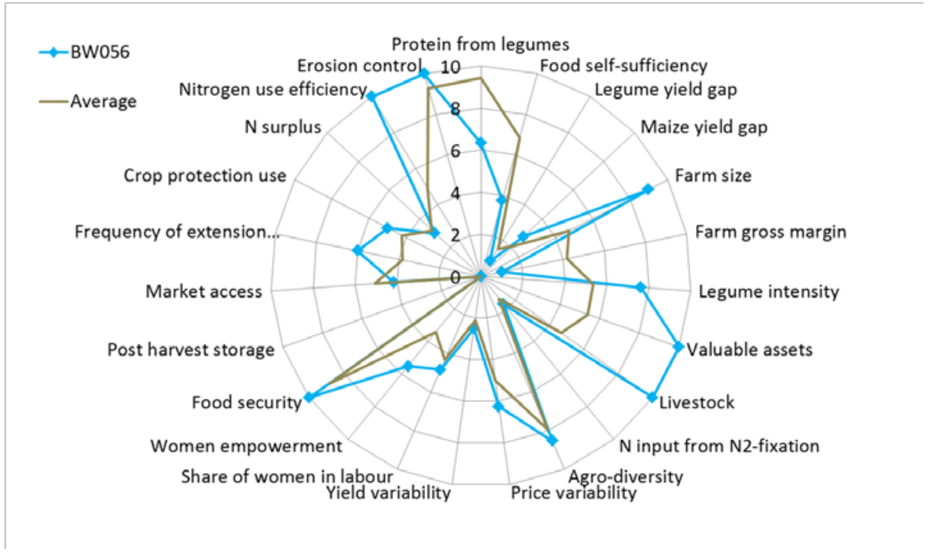

BW057
Average
Protein from legumes
Food self-sufficiency
Legume yield gap
Maize yield gap
Farm size
Farm gross margin
Legume intensity
Valuable assets
Livestock
N input from N2-fixation
Agro-diversity
Price variability
Yield variability
Share of women in labour
Women empowerment
Food security
Post harvest storage
Market access
Frequency of extension...
Crop protection use
N surplus
Nitrogen use efficiency
Erosion control
10
8
6
4
2
0


BW112
Average
Protein from legumes
Food self-sufficiency
Legume yield gap
Maize yield gap
Farm size
Farm gross margin
Legume intensity
Valuable assets
Livestock
N input from N2-fixation
Agro-diversity
Price variability
Yield variability
Share of women in labour
Women empowerment
Food security
Post harvest storage
Market access
Frequency of extension...
Crop protection use
N surplus
Nitrogen use efficiency
Erosion control
10
8
6
4
2
0


BW109
Average
Protein from legumes
Food self-sufficiency
Legume yield gap
Maize yield gap
Farm size
Farm gross margin
Legume intensity
Valuable assets
Livestock
N input from N2-fixation
Agro-diversity
Price variability
Yield variability
Share of women in labour
Women empowerment
Food security
Post harvest storage
Market access
Frequency of extension...
Crop protection use
N surplus
Nitrogen use efficiency
Erosion control
10
8
6
4
2
0


BW094
Average
Protein from legumes
Food self-sufficiency
Legume yield gap
Maize yield gap
Farm size
Farm gross margin
Legume intensity
Valuable assets
Livestock
N input from N2-fixation
Agro-diversity
Price variability
Yield variability
Share of women in labour
Women empowerment
Food security
Post harvest storage
Market access
Frequency of extension...
Crop protection use
N surplus
Nitrogen use efficiency
Erosion control
10
8
6
4
2
0

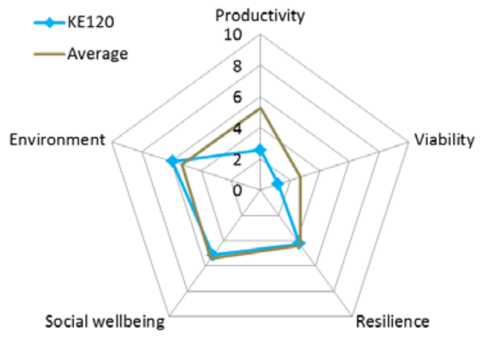

BW055
Average
Protein from legumes
Food self-sufficiency
Legume yield gap
Maize yield gap
Farm size
Farm gross margin
Legume intensity
Valuable assets
Livestock
N input from N2-fixation
Agro-diversity
Price variability
Yield variability
Share of women in labour
Women empowerment
Food security
Post harvest storage
Market access
Frequency of extension...
Crop protection use
N surplus
Nitrogen use efficiency
Erosion control
10
8
6
4
2
0

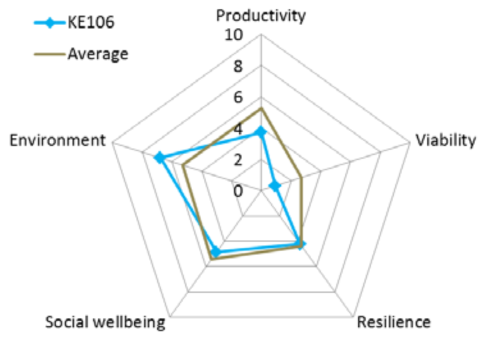

BW056
Average
Protein from legumes
Food self-sufficiency
Legume yield gap
Maize yield gap
Farm size
Farm gross margin
Legume intensity
Valuable assets
Livestock
N input from N2-fixation
Agro-diversity
Price variability
Yield variability
Share of women in labour
Women empowerment
Food security
Post harvest storage
Market access
Frequency of extension...
Crop protection use
N surplus
Nitrogen use efficiency
Erosion control
10
8
6
4
2
0

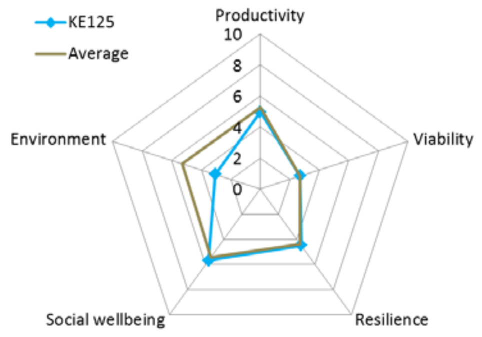
Annex V – Results of spider web indicators at the level of principles

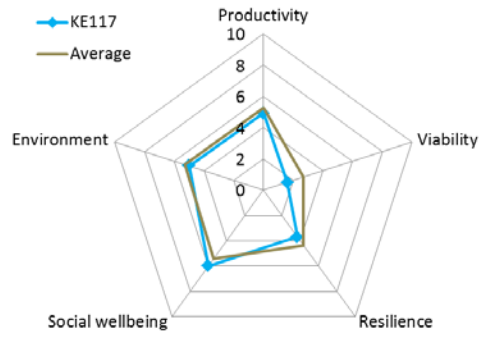
- Households are ordered according to their overall sustainability score (average across principles)
- The Averages (grey line) are the average scores per research site.

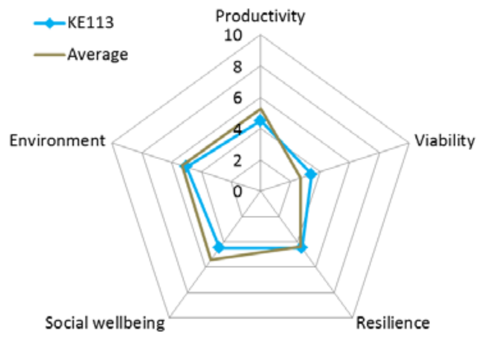
Kenya – Migori

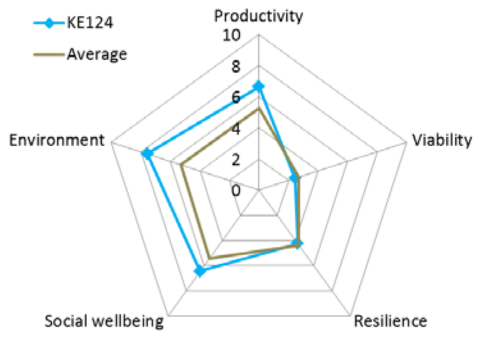


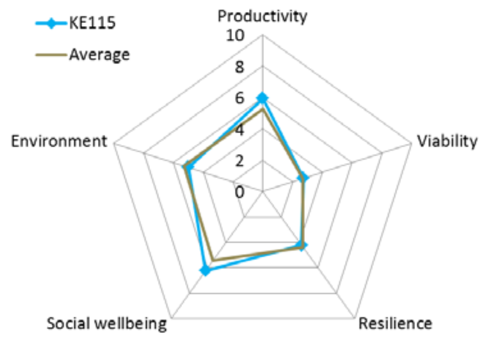


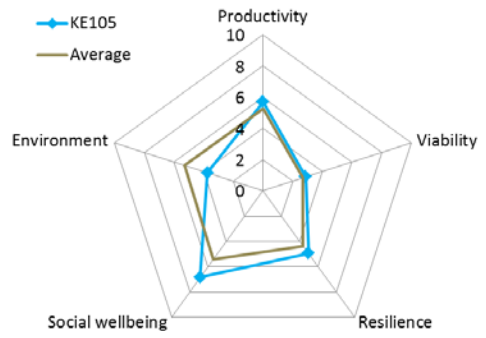


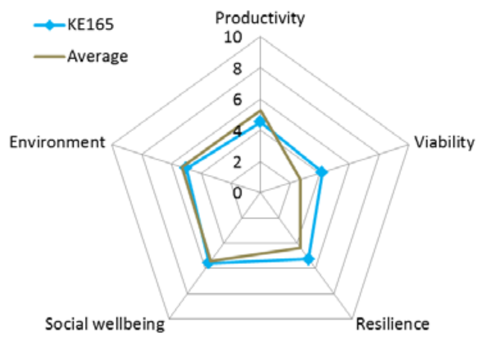


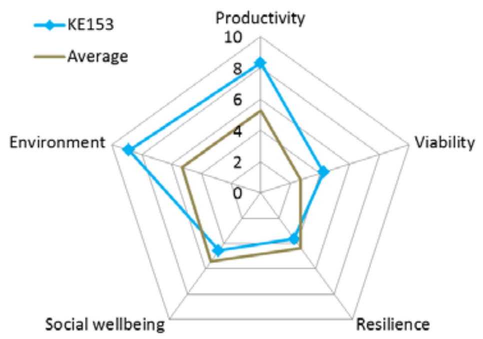




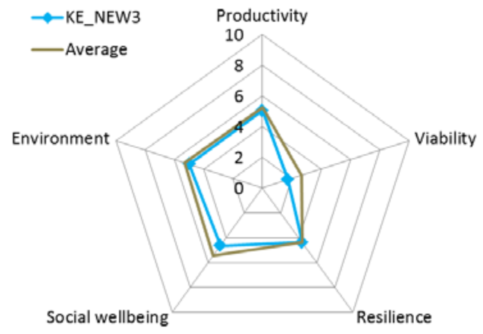


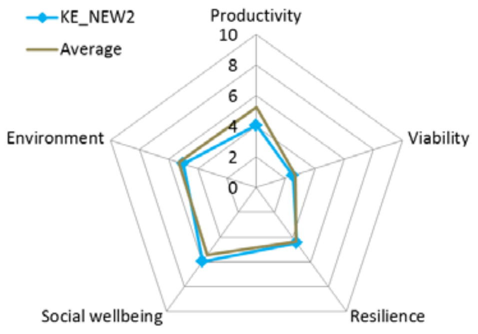


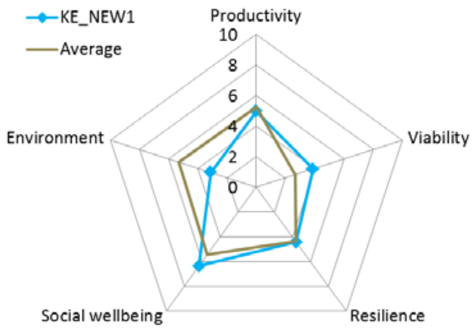




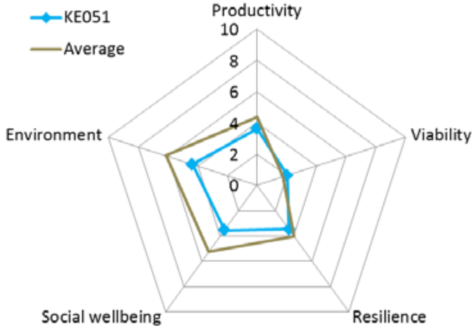
Kenya – Migori, selected for soyabean

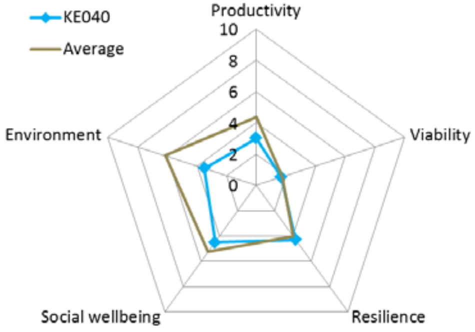


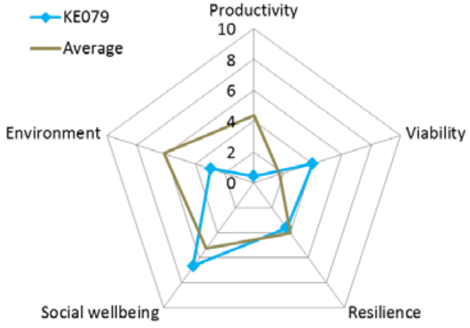


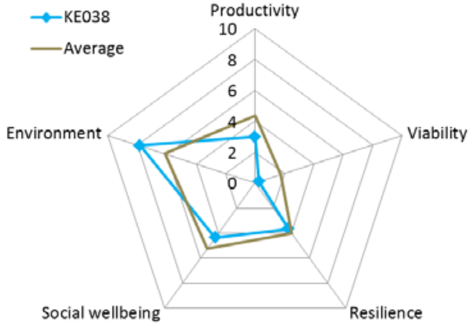


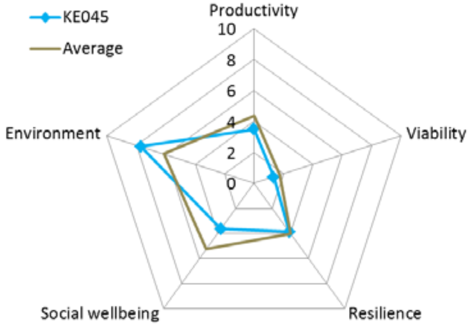
Kenya – Vihiga

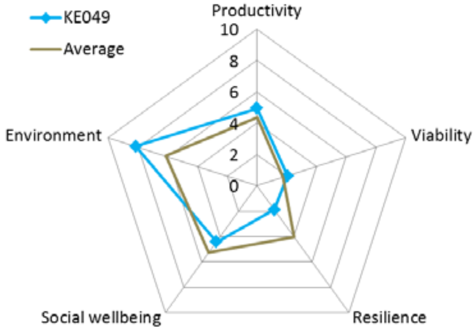


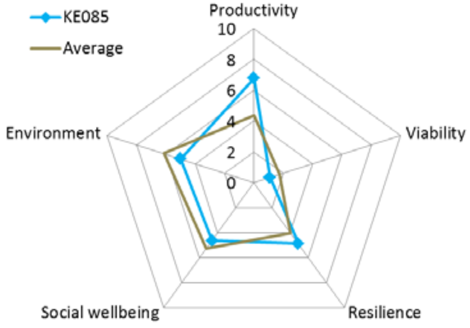


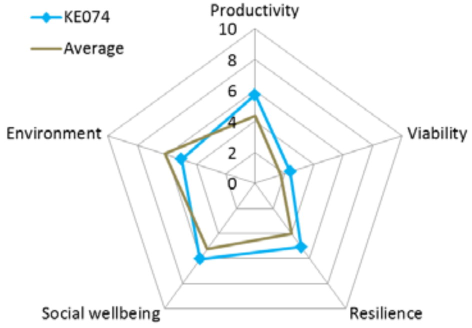


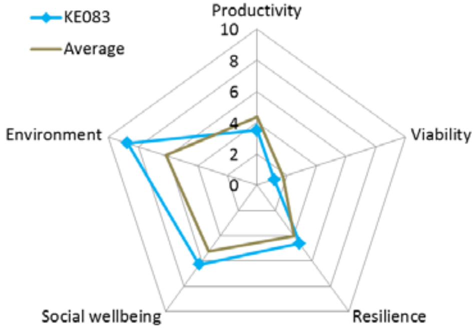


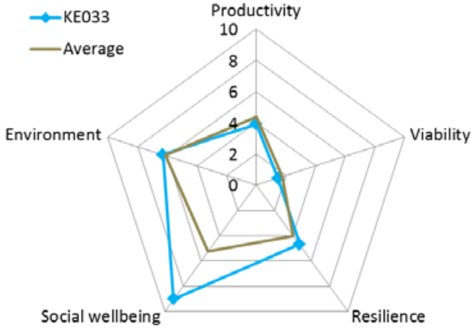




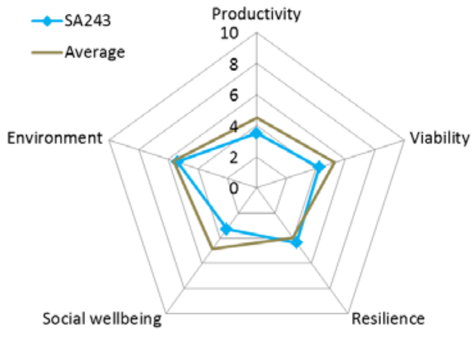


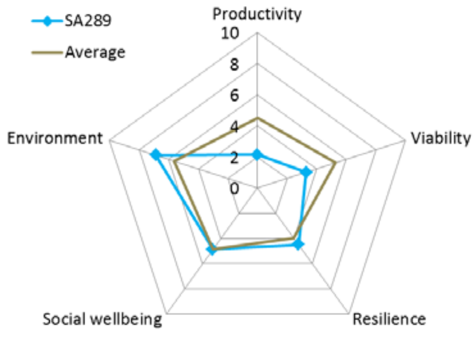


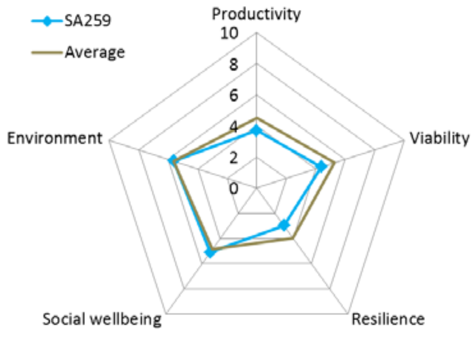


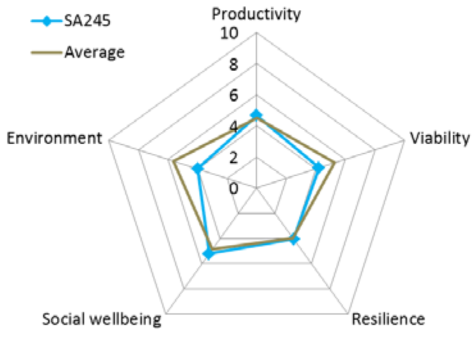


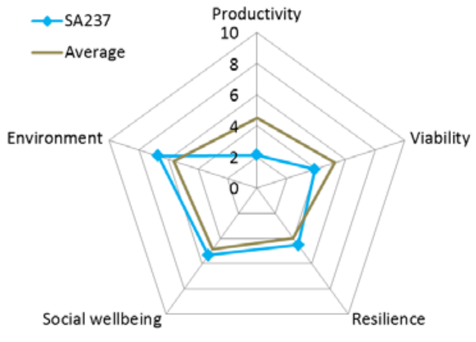
Ghana – Savelugu

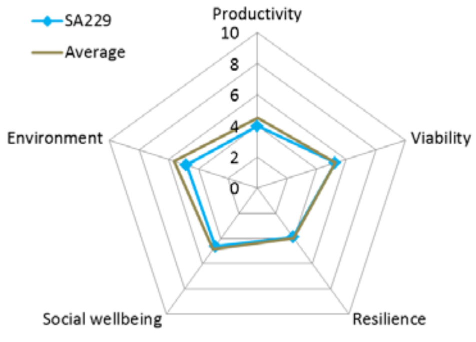


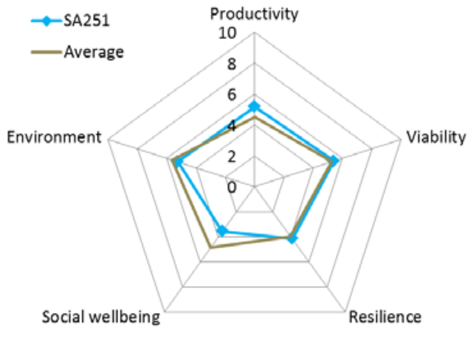


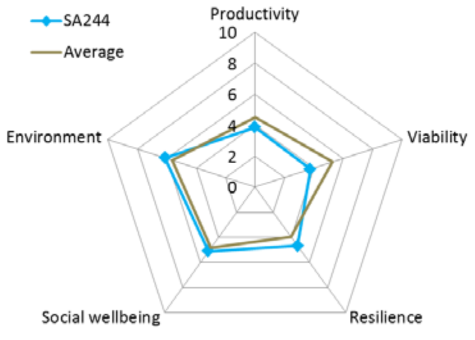


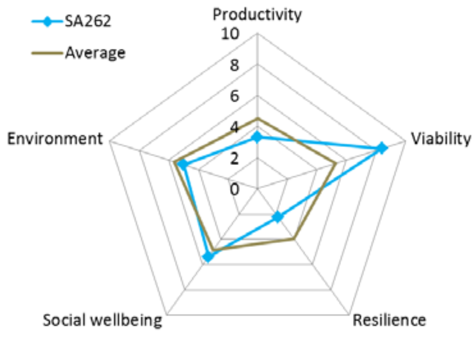


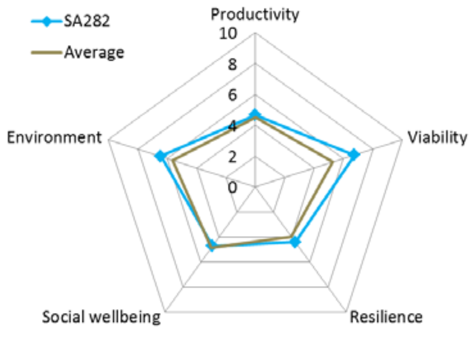












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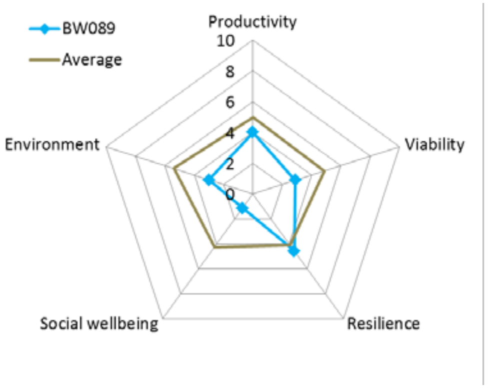

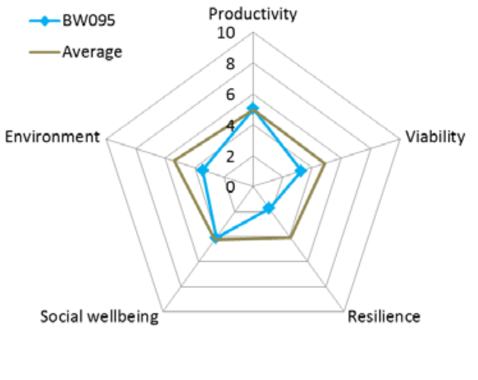

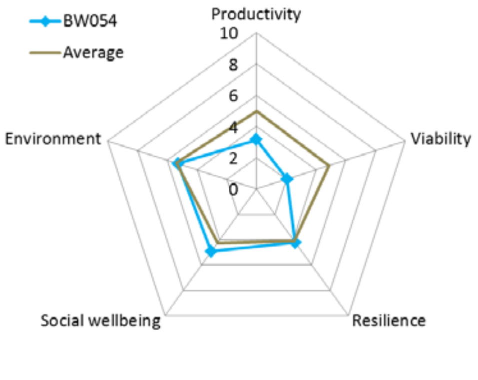

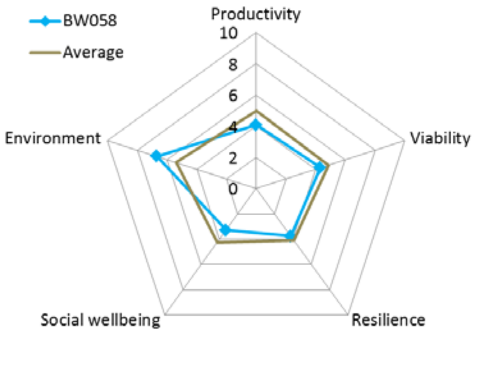

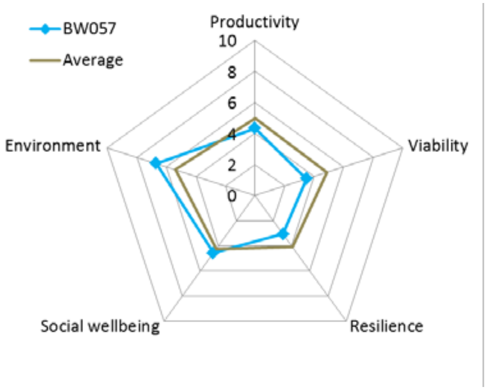

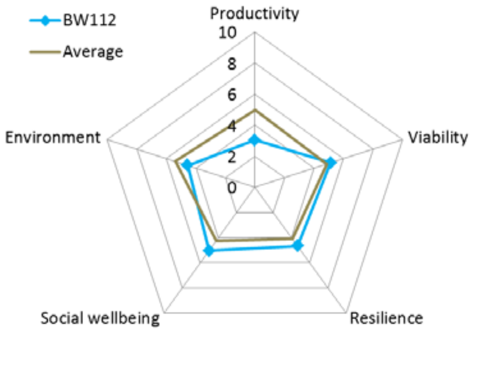

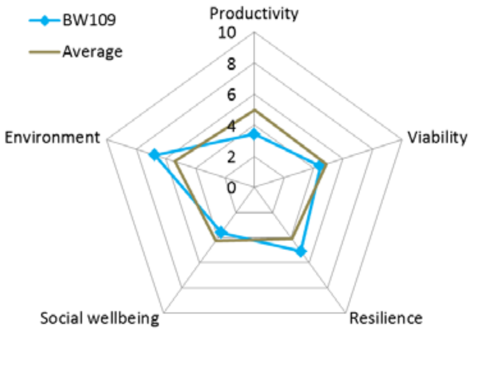

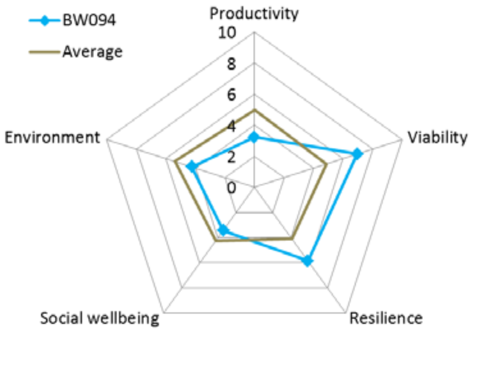

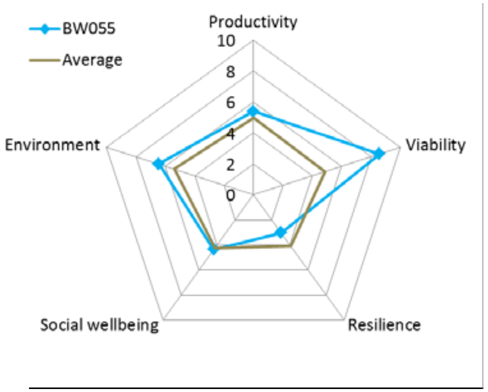

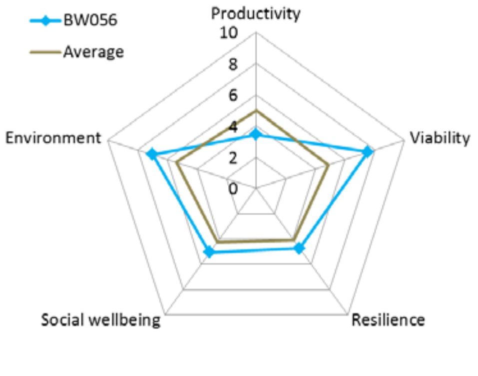

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List of project reports

1. N2Africa Steering Committee Terms of Reference
2. Policy on advanced training grants
3. Rhizobia Strain Isolation and Characterisation Protocol
4. Detailed country-by-country access plan for P and other agro-minerals
5. Workshop Report: Training of Master Trainers on Legume and Inoculant Technologies (Kisumu Hotel, Kisumu, Kenya-24-28 May 2010)
6. Plans for interaction with the Tropical Legumes II project (TLII) and for seed increase on a country-by-country basis
7. Implementation Plan for collaboration between N2Africa and the Soil Health and Market Access Programs of the Alliance for a Green Revolution in Africa (AGRA) plan
8. General approaches and country specific dissemination plans
9. Selected soyabeans, common beans, cowpeas and groundnuts varieties with proven high BNF potential and sufficient seed availability in target impact zones of N2Africa Project
10. Project launch and workshop report
11. Advancing technical skills in rhizobiology: training report
12. Characterisation of the impact zones and mandate areas in the N2Africa project
13. Production and use of rhizobial inoculants in Africa
18. Adaptive research in N2Africa impact zones: Principles, guidelines and implemented research campaigns
19. Quality assurance (QA) protocols based on African capacities and international existing standards developed
20. Collection and maintenance of elite rhizobial strains
21. MSc and PhD status report
22. Production of seed for local distribution by farming communities engaged in the project
23. A report documenting the involvement of women in at least 50% of all farmer-related activities
24. Participatory development of indicators for monitoring and evaluating progress with project activities and their impact
25. Suitable multi-purpose forage and tree legumes for intensive smallholder meat and dairy industries in East and Central Africa N2Africa mandate areas
26. A revised manual for rhizobium methods and standard protocols available on the project website
27. Update on Inoculant production by cooperating laboratories
28. Legume Seed Acquired for Dissemination in the Project Impact Zones
29. Advanced technical skills in rhizobiology: East and Central African, West African and South African Hub
30. Memoranda of Understanding are formalized with key partners along the legume value chains in the impact zones
31. Existing rhizobiology laboratories upgraded
32. N2Africa Baseline report
33. N2Africa Annual country reports 2011

34. Facilitating large-scale dissemination of Biological Nitrogen Fixation
35. Dissemination tools produced
36. Linking legume farmers to markets
37. The role of AGRA and other partners in the project defined and co-funding/financing options for scale-up of inoculum (banks, AGRA, industry) identified
38. Progress Towards Achieving the Vision of Success of N2Africa
39. Quantifying the impact of the N2Africa project on Biological Nitrogen Fixation
40. Training agro-dealers in accessing, managing and distributing information on inoculant use
41. Opportunities for N2Africa in Ethiopia
42. N2Africa Project Progress Report Month 30
43. Review & Planning meeting Zimbabwe
44. Howard G. Buffett Foundation – N2Africa June 2012 Interim Report
45. Number of Extension Events Organized per Season per Country
46. N2Africa narrative reports Month 30
47. Background information on agronomy, farming systems and ongoing projects on grain legumes in Uganda
48. Opportunities for N2Africa in Tanzania
49. Background information on agronomy, farming systems and ongoing projects on grain legumes in Ethiopia
50. Special Events on the Role of Legumes in Household Nutrition and Value-Added Processing
51. Value chain analyses of grain legumes in N2Africa: Kenya, Rwanda, eastern DRC, Ghana, Nigeria, Mozambique, Malawi and Zimbabwe
52. Background information on agronomy, farming systems and ongoing projects on grain legumes in Tanzania
53. Nutritional benefits of legume consumption at household level in rural sub-Saharan Africa: Literature study
54. N2Africa Project Progress Report Month 42
55. Market Analysis of Inoculant Production and Use
56. Identified soyabean, common bean, cowpea and groundnut varieties with high Biological Nitrogen Fixation potential identified in N2Africa impact zones
57. A N2Africa universal logo representing inoculant quality assurance
58. M&E Workstream report
59. Improving legume inoculants and developing strategic alliances for their advancement
60. Rhizobium collection, testing and the identification of candidate elite strains
61. Evaluation of the progress made towards achieving the Vision of Success in N2Africa
62. Policy recommendation related to inoculant regulation and cross border trade
63. Satellite sites and activities in the impact zones of the N2Africa project
64. Linking communities to legume processing initiatives
65. Special events on the role of legumes in household nutrition and value-added processing
66. Media Events in the N2Africa project

67. Launch N2Africa Phase II – Report Uganda
68. Review of conditioning factors and constraints to legume adoption and their management in Phase II of N2Africa
69. Report on the milestones in the Supplementary N2Africa grant
70. N2Africa Phase II Launch in Tanzania
71. N2Africa Phase II 6 months report
72. Involvement of women in at least 50% of all farmer related activities
73. N2Africa Final Report of the First Phase: 2009-2013
74. Managing factors that affect the adoption of grain legumes in Uganda in the N2Africa project
75. Managing factors that affect the adoption of grain legumes in Ethiopia in the N2Africa project
76. Managing factors that affect the adoption of grain legumes in Tanzania in the N2Africa project
77. N2Africa Action Areas in Ethiopia, Ghana, Nigeria, Tanzania and Uganda in 2014
78. N2Africa Annual report Phase II Year 1
79. N2Africa: Taking Stock and Moving Forward. Workshop report
80. N2Africa Kenya Country Report 2015
81. N2Africa Annual Report 2015
82. Value Chain Analysis of Grain Legumes in Borno State, Nigeria
83. Baseline report Borno State
84. N2Africa Annual Report 2015 DR Congo
85. N2Africa Annual Report 2015 Rwanda
86. N2Africa Annual Report 2015 Malawi
87. Contract Sprayer in Borno State, Nigeria
88. N2Africa Baseline Report II Ethiopia, Tanzania, Uganda, version 2.1
89. N2Africa rhizobial isolates in Kenya
90. N2Africa Early Impact Survey, Rwanda
91. N2Africa Early Impact Survey, Ghana
92. Tracing seed diffusion from introduced legume seeds through N2Africa demonstration trials and seed-input packages
93. The role of legumes in sustainable intensification – priority areas for research in northern Ghana
94. The role of legumes in sustainable intensification – priority areas for research in western Kenya
95. N2Africa Early Impact Survey, Phase I
96. Legumes in sustainable intensification – case study report PROIntensAfrica

Partners involved in the N2Africa project

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Diobass

Eglise Presbyterienne Rwanda

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