Supporting smallholder farmers' decisions on legume use in East Africa – the LegumeCHOICE approach

[1]DUNCAN, A.J., [2]ÖBORN, I., [3]NZIGUHEBA, G., [1]TAMENE TEMESGEN, [1,2,4]MUONI, T., [2]OKEYO, I., [5]SHILULI, M., [6]BERHANU TADESSE, [7]WALANGULULU, J., [3]VANLAUWE, B.

1. International Livestock Research Institute, PO Box 5689, Addis Ababa, Ethiopia; 2. World Agroforestry Centre (ICRAF), Nairobi, Kenya; 3. International Institute of Tropical Agriculture, Nairobi, Kenya. 4. Swedish University of Agricultural Sciences (SLU), Uppsala, Sweden. 5. Kenya Agriculture and Livestock Research Organization, Kenya 6. Oromia Agricultural Research Institute, Bako Research Centre, Ethiopia; 7. Université Catholique de Bukavu, DRC

Summary

East African farming systems are diverse but are generally characterized by mixed crop-livestock production with a mix of cereals, roots, legumes, livestock and tree crops. Legumes offer many livelihood and natural resource management benefits but are generally underutilized in smallholder systems especially in the case of tree and forage legumes. Through a research for development project called LegumeCHOICE we developed a classification of multipurpose legumes and defined the various farm functions that each class and species fulfilled using an expert scoring system. We went on to develop a simple decision support tool based on this work to help decision makers prioritize different legume types to meet expressed needs of smallholders in East Africa when considering legume interventions.

Introduction

East Africa is biophysically diverse. Altitude and topography range from lowland coastal zones and plains to highland landscapes over 1500 m with steep slopes. Soils are also very diverse, ranging from young soils developed on volcanic deposits in the Rift Valley, to highly weathered old soils of various types, which dominate most of the region. Agriculture is mainly rainfed, and both unimodal and bimodal rainfall patterns are found within the region and even within some countries. The result of this diversity is a variety of farming systems, where the Maize-Mixed Farming System with legume intercropping is a crop-livestock system dominating in the sub-humid areas of Southern and Eastern Africa (Dixon et al 2001; Garrity et al 2017). A high proportion of the population is engaged in agricultural activities, and depends on the farm for their food and nutrition security and their livelihood. Due to favourable biophysical conditions, the highlands are highly populated, with densities as high as 500 persons/km2 (Himeidan and Kweka, 2012). These high densities lead to small farm sizes, with most smallholders cultivating less than 1 ha (Rapsomanikis, 2015). Livestock is a key component of the East Africa farming system. Within farming communities, farming households have varying access to resources with poorer households commonly having less livestock, land and labour. This variation in resource endowment has been conceptualized into a series of household types (Tittonell et al, 2010). This range of biophysical conditions along with access to and allocation of resources, plays a major role in the integration of legumes into existing farming systems.

Legumes are an underutilized resource in mixed farming systems in East Africa. These systems tend to be dominated by staple cereal crops such as maize and teff, or starchy roots such as cassava. Legumes do feature in these systems, mainly in the form of grain legume intercrops such as field beans in Kenya and DRC or as relay crops such as lentils in Ethiopia. However the extent of legume use is low relative to the potential benefits that could be derived from their wider utilization. Legumes offer multiple benefits in these systems including provision of food, livestock feed and enhanced soil fertility as described below. These contributions deal with many of the constraints inherent to smallholder livelihoods in East Africa including shortage of nutrient dense foods, shortage of high quality livestock feed and inadequate plant nutrients to allow food crops to yield to their potential.

The aim of this paper is to introduce (i) the role and potential of multipurpose legumes in mixed crop-livestock smallholder farming systems in East Africa, and (ii) a legume decision framework to support smallholder's decisions on legume integration and intensification

Drivers of change and role of legumes in dealing with them

Farming systems are affected by a wide range of drivers of change that can have varying impacts on legume integration in such systems and on the contributions legumes make to the functioning of these systems. Some of the most visible pressures include population growth (Josephson et al. 2014) and consequent land fragmentation and climate change, often expressed as increased variability in rainfall patterns (Thornton et al. 2014). Population growth is associated with the disappearance of fallow periods and the requirement to intensify agricultural production in order to generate more produce per unit area of land.

While herbaceous annual or perennial legumes, the latter often erroneously referred to as 'fertilizer trees' (Ajayi et al. 2011), are known to fix substantial amounts of N and producing high quality biomass (Mafongoya et al. 2006; Ibewiro et al. 2001), their uptake by farmers have been limited at most under conditions where fallows are still possible and certainly in areas with high population densities, mostly because such legumes require investments in labour without generating immediate outputs (Giller, 2001). On the contrary, dual purpose grain legumes could supply part of the N required by cereal when grown in rotation with these crops (Sanginga. 2003) or provide fodder in areas with presence of livestock, and especially zero-grazed livestock. Increased climate variability often results in farmers preferring short duration grain legumes (e.g., cowpea or beans) or varieties (e.g., short duration soybean) (Snapp and Silim. 2002), at the cost of extra inputs of N via BNF and extra production of crop residues.

As with other crops, investments in legume production through intensification and/or expansion of production requires profitable access to agro-inputs such as seeds, legume-specific fertilizer, and rhizobium inoculants, the latter mostly for legumes that are not commonly forming a functional symbiosis with indigenous rhizobium populations. It also requires access to markets for grain legumes or products derived from grain legumes (e.g., soymilk from soybean). Engagement of farmers with input and output markets is often backstopped by an effective extension system. Consequently, investments in facilitating access to agro-inputs and produce markets through subsidy schemes (e.g, the Crop Intensification Program in Rwanda has beans and soybean as priority crops), improved rural infrastructure, or market information systems will also impact on the presence of legumes in farming systems. Notwithstanding the multiple benefits that legumes can provide, expansion of legume production is mostly driven by increased market access (e.g., pigeon pea in East Africa or chickpea and beans in Ethiopia) rather than any other potential benefits such as the provision of firewood, fodder, or protein for household consumption. In a sense, farmers treat legumes as any other crop whereby investment decision are largely driven by potential market access (Frelat et al. 2016).

Legumes Types in East Africa

Legumes can be classified into various types, based on their form, growth duration and use. Some are seasonal while others are perennial; some are mainly grown for their grains, others mainly for their leaves; some have woody stems, others not. Given the multiple types of legumes, the LegumeCHOICE project1 used expert opinion to classify legumes as part of the process of defining legume attributes for the development of a legume decision support tool. Six classes were defined: Grain legumes (seasonal and perennial), herbaceous legumes (seasonal and perennial), tree legumes (coppicing and non-coppicing).

Grain legumes are mainly grown for their grains (Table 1). These include the widely used common bean along with faba beans, chickpeas, lentils, soybean and many others. Such grain legumes are an important source of household nutrition as well as being traded for cash income. Growth duration for seasonal grains is limited to one season (e.g. cowpea, groundnut), whereas the perennials grow over multiple years (e.g. pigeon pea). Herbaceous legumes lack woody stems and are grown mainly for fodder or for soil fertility improvement. Forage legumes are sometimes the same species as grain legumes but have been bred for biomass production. Examples include cow pea which has grain and forage varieties. Other herbaceous legumes species are purely used as forage. Some, such as Lablab species are annuals requiring reseeding after harvest while others such as Desmodium species have some regrowth potential following harvest. Alfalfa can tolerate multiple harvests over several years. The seasonal types include Mucuna and Crotalaria, while the perennial types include Desmodium and Alfalfa. Tree legumes are characterized by their woody stems and a shrub or tree form, and they are often multipurpose trees used as sources of livestock feed, fuel wood as well as fulfilling other functions such as provision of stakes e.g. for climbing beans. The coppicing type includes legume trees that produce regrowth after pruning such as Calliandra and Gliricidia, whereas the non-coppicing type does not sustain pruning: e.g. Sesbania and Faidherbia.

Most legumes show at least some multi-functionality. For example, although crops such as lentil are grown primarily for grain, their straws are used to feed livestock and they are used as key components of rotations to enhance soil fertility and reduce disease build up. Similarly, some herbaceous legumes such as Mucuna are used as green manure to improve soil fertility but are also used as livestock feed. This multi-functionality is not always acknowledged in research and extension efforts in East Africa with scientists often over-emphasizing grain production over the many other important functions that legumes deliver to smallholder farmers.

---

[1] LegumeCHOICE: Realizing the underexploited potential of multi-purpose legumes towards improved livelihoods and a better environment in crop-livestock systems in East & Central Africa. Project funded by German Federal Ministry for Economic Cooperation and Development (BMZ). Apr 2014 – Mar 2017

Table 1 – Examples of the various legume types and their contributions to various legume functions[2].

Legume types	Example of legume species		Legume Functions			Reference
	Common name	Scientific name	Grain yield (kg DM/year)	Feed (kg DM/year)	Soil fertility (BNF kg/ha)	
Grain legume seasonal	Common bean	*Phaseolus vulgaris*	600-2000	3500-5100	60-80	Fernández-Luqueño et al., 2010; Maingi et al., 2001; Manrique et al., 1993; Dakora and Keya, 1997
Grain legume perennial	Pigeon pea	*Cajanus cajan*	700-1400	1390-11000	40-250	Kumar Rao and Dart, 1987; Mhlanga et al., 2015
Grain legume seasonal	Faba bean	*Vicia faba*	904- 5300	6000	32-332	Mathews 2003; Jensen 1986; Manrique et al., 1993; Amauel et al., 2000; Denton et al., 2013; Jensen 1986
Grain legume seasonal	Cowpea	*Vigna unguiculata*	381-1147	813-3348	15-240	Mhanga et al., 2015; Bado et al., 2005; Dakora and Keya (1997); Aikins and Afuakwa (2008); Agyeman et al., 2014; Mullen 1999; Sanginga 2003
Grain legume seasonal	Soybean	*Glycine max*	340-3030	2480-3010	24-188	Toomsan et al., 1995; Ojiem et al., 2014; Graham and Vance 2003
Herbaceous legume, perennial	Lucerne	*Medicago sativa*		4072-17918	37.8-407	Moghaddam et al., 2015; Taraken 2014
Herbaceous legume, perennial	Siver leaf desmodium	*Desmodium uncinatum*		514-3221	178	Jones, 1989; Clatworthy, 1984; Haque and Jutzi, 1984
Herbaceous legume, seasonal	Mucuna	*Mucuna pruriens*	1482	2750-12000	44-319	Okito et al., 2004; Eillitta et al., 2003; Kurniaturn Hairiah and Meine van Noordwijk (undated); Mhlanga and Thierfelder 2015; Ojiem 2007
Herbaceous legume, seasonal	Lablab	*Lablab purpureus*	50-1400	661-8701	215	Ojiem et al., 2014; Sanginga 2002; Hassan et al., 2004; Gbaranel et al., 2004
Tree legume, coppicing	Calliandra	*Calliandra calothyrsus*		2192-7830	9.2-110	Angima et al., 2002; Gunaratne et al., 2000; Nyaata et al., 2002; Berhe and Mohammed-Saleem, 1996
Tree legume, coppicing	Gliricidia	*Gliricidia sepium*		2213-15520	13-151	Bray and Tatang Ibrahim, 1993; Dreyfus et al., 1987; de S. Liyanage et al., 1994; Howeler et al., 1998
Tree legume, non-coppicing	Sesbania	*Sesbania sesban*		300-4600	84-363	Karachi and Matata, 1997; Qamar et al., 2014
Tree legume, non-coppicing	Acacia	*Acacia angustissima*		41500 (2 years)	218 (2years)	Mafongoya and Dzowela (1999)

[2] For details of papers cites contact the authors

How legumes contribute to smallholder livelihoods

Legumes contribute in many ways to farmer livelihoods and as part of the LegumeCHOICE project we systematically defined the various “farm functions" that legumes fulfil.

Soil fertility improvement is a defining characteristic of legumes. Through the action of symbiotic bacteria in root nodules, legumes can fix atmospheric nitrogen. Residual biomass following harvesting of the crop can therefore positively contribute to soil nitrogen status for subsequent crops. In some cases, legumes are grown specifically for their contribution to soil nitrogen status as green manure crops. More often though, improved soil fertility is a side benefit of crops that are grown for other primary purposes, notably food or fodder production.

Provision of household nutrition. Grain legumes are highly nutritious food and the most important source of protein, calcium and other minerals and vitamins for many smallholder families in sub-Saharan Africa, especially for women and children. Also, the leaves of legumes can be a valuable and nutritious food.

Income. Although often grown for home-consumption, legumes can be important cash crops in East African farming enterprises providing substantial cash income through sale of grain and sometimes fodder.

Livestock feed. Legumes are also a good source of feed for livestock. Partly because of their nitrogen fixing attributes, legume biomass tends to have higher nitrogen concentrations than, for example cereal crop residues. Nitrogen is usually in deficit in livestock diets in East Africa and the additional nitrogen that legume biomass provides can substantially improve livestock productivity. Additional nitrogen derived from legume biomass can markedly improve the utilization of poor quality cereal residues which are the dominant basal feed for livestock in East Africa. They do this by supplying nitrogen to rumen micro-organisms allowing a more active fermentation in the rumen.

Fuel. Locally, across East Africa, there is an acute scarcity of fuelwood energy that is a daily need for most people. Legumes provide fuelwood and hence are an integral part of household subsistence needs. Fast-growing tree legumes: Calliandra, Gliricidia and Leucaena found across East Africa are commonly used for fuel wood. Additionally, crop residues of grain legumes including soya, cowpeas and beans are used as kindling and occasionally for cooking.

Soil protection from erosion. Different legumes have proven to be beneficial in reducing soil nutrients and water loss through erosion. Most grain legumes such as beans, cowpeas, green grams have broad leaves which cover and protect top soils from the splash effect from heavy rain drops, and the subsequent washing away of nutrients. Tree legumes; Calliandra, Gliricidia, Leucaena and others hold the soils firm thereby reducing washing away by rains. Incorporation of organic matter from legumes either has been shown to improve soil structure and water retention capacity.

Legume Use in East Africa

Household surveys carried out in six LegumeCHOICE field sites in DRC, Ethiopia and Kenya showed that the majority (60-90%) of households are growing legumes either intercropped (often with maize) or as sole crop. The proportion of land used for legumes (intercropped or sole crop) ranged from 20% in Ethiopia, 36% in Kenya and 42% in DRC. A significant part of the household income came from selling grain legumes, 15-20% in DRC and Kenya and 5-10% in Ethiopia.

Although grain legumes are reasonably prominent crops in East African mixed farming systems, use of tree and forage legumes is relatively scant and one could argue that the various benefits that these multipurpose legume types provide are not being fully realized in East African mixed farming systems. The reasons for the lower than expected use of tree and forage legumes among smallholders are many. Tree legumes can be difficult to establish and are a "knowledge intensive" technology. The same applies to forage legumes. The link between their productivity and the generation of a marketable product, for example, milk is less direct than, for example, grain legumes. This may lead farmers to give them less attention. For forage legumes, farmers may be reluctant to devote scarce land and labour to activities which compete with staple food production. Forage legumes can place considerable demands on land and labour. Further, the environmental benefits of tree and forage legume use, while important, can be long-term and farmers may be more focused on the immediate need to feed a family and derive an income in the current season. Security of land tenure is a further issue for technologies which build natural capital because of the long-term nature of the investment.

Matching choice of legumes with farmer needs – the LegumeCHOICE tool

Recognising the multiple benefits that farmers potentially derive from legumes, we have developed a decision support tool to match farmers' needs with the various benefits that different legume types and species offer. The LegumeCHOICE tool helps to match legume options to the needs of farmers in a community. It does this through 3 main elements. Firstly, a Context Assessment is carried out with the local community using a simple questionnaire conducted with a group of farmers. This provides scores for various important constraints to legume use including land availability, labour availability and seed supply. Secondly, a Community Needs Assessment is conducted using participatory exercises to come up with a simple quantified assessment of the various legume benefits that farmers value. Thirdly, an Agro-Ecological Assessment is carried out by applying scores to various agro-ecological variables depending on local conditions. These variables include rainfall, temperature, altitude and soil pH. These 3 elements then feed into an overall score sheet which checks scores against a series of legume options to come up with a shortlist of promising legume species based on the constraints and opportunities found in the local community.

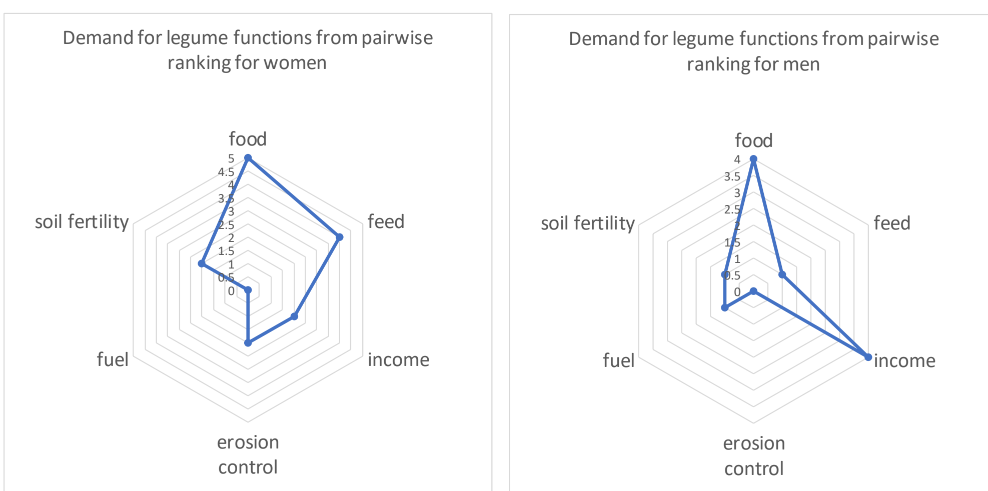

Figure 1. Example of output from the LegumeCHOICE tool illustrating the different expressed needs in relation to legume interventions among women (left) and men (right). Data from the Nyaribari field site in Kenya.

The LegumeCHOICE tool has been applied so far in Ethiopia, Kenya and DRC. The tool has proved useful for informing decisions about which legume-based interventions show most promise in terms of delivering the various functions that farmers want from legume technologies. Use of the tool has highlighted the fact that different farmer groups (e.g. men and women) have different requirements from legumes. For example, in Nyaribari in Kenya male respondents expressed a strong requirement for food and income from any new legume intervention while female respondents, while expressing a requirement for food showed a broader requirement for other legume functions including livestock feed, soil fertility improvement and erosion control. Similar variable results were found when comparing different farm types. This all goes to support the need for targeted interventions for different user groups which is the point of the LegumeCHOICE tool. The tool is at a prototype stage but shows considerable promise for supporting smarter decision making around legume use in smallholder systems. Use of the tool could broaden the perspectives of extension workers and development workers when working with communities to enhance livelihoods and natural capital. Some work remains to further enhance the database underlying the tool and to develop a more user-friendly front end and this will be the next phase of the research.

References

Ajayi, C.O., Place, F., Akinnifesi, K. F., Sileshi, W.G. (2011). Agricultural success from Africa: the case of fertilizer tree systems in southerb Africa 9Malawi, Tanzania, Mozambique, Zambia and Zimbabw). International Journal of Agricultural Sustainability 9: 129-136.

Dixon, J., Gulliver, A., Gibbon, D., and Hall, M. (2001). "Farming systems and poverty: Improving farmers' livelihoods in a changing world," FAO and World Bank Rome and Washington, D.C.

Frelat, R., Lopez-Ridaura, S., Giller, KE, Herrero, M, et al. (2016). Drivers of houshold food availability in sub-Saharan Africa based on big data from small farms. PNAS 113: 458-463.

Garrity, D., Dixon, J., and Boffa, J.-M (2017). Understanding African Farming Systems as a basis for Sustainable Intensification. In: Öborn, I., Vanlauwe, B., Philips, M., Thomas, R., Brooijmans, W., (eds.). Sustainable Intensification in Smallholder agriculture. An integrated systems research approach. Earthscan Food and Agriculture, Routledge, London, pages

Giller, K.E, (2001). Nitrogen fixation in tropical cropping systems. Second edition. CABI

Himeidan EY, Kweka JE (2012). Malaria in East African highlands during the past 30 years: impact of environmental changes. Frontiers in physiology 3: 1-11. doi:10.3389/fphys.2012.00315

Ibewiro, B., Onuh, M., Sanginga, N., Vanlauwe, B., Merckx,. (2001). Symbiotic performance of herbaceous legumes in tropical cover cropping systems. The Scientific World 1: 17-21.

Josephson, LA., Ricker-Gilbert, J., Florax, J.G.M.R., 2014. How does population density influence agricultural intensification and productivity? Evidence from Ethiopia. Food Policy 48: 142-152.

Mafongoya LP., Kuntashula, E., Sileshi, G (2006). Managing soil fertility and nutrient cycles through fertilizer trees in Southern Africa. In Uphoff, N., Ball, S.A., Palm, C., Fernandes, E., Pretty, J., Herren, H., Sanchez, P., Husson, O., Sanginga, N., Laing, M., Thies, J. Biological approaches to sustainable soil systems. Taylor &Francis, UK 273-289.

Rapsomanikis G (2015). The economic lives of smallholder farmers. An analysis based on household data from nine countries. FAO, Rome.

Sanginga. N., (2003). Role of biological nitrogen fixation in legume based cropping systems; a case study of west Africa farming system. Plant Soil 252:25-39

Snapp, A.S., Silim, S.N. (2002). Farmer preference and legume intensification for low nutrient environments. Plant and Soil 245:181-192.

Thornton, KP., Ericksen, PJ., Herrero, M., Challinor, JA., 2014. Climate variability and vulneraability to climate change: a review. Global Chanf Biology 20:3313-3328

Tittonell, P., Vanlauwe, B., Leffelaar, P.A., Shepherd, K., Giller, K.E., 2005. Exploring diversity in soil fertility management of smallholder farms in western Kenya: II: within farm variability in resource allocation, nutrient flows and soil fertility status. Agric., Ecosyst. Environ. 110, 166-184.

Kindu M., Duncan AJ, Valbuena D, Gerard B, Dagnachew B, Mesfin B, Deion J (2014). Intensification of Crop-Livestock Farming Systems in East Africa: A Comparison of Selected Sites in Highlands of Ethiopia and Kenya. In: Vanlauwe B., et al. (eds.), Challenges and Opportunities for Agricultural Intensification of the Humid Highland Systems of Sub-Saharan Africa, DOI 10.1007/978-3-319-07662-1_2

Bekele Sh., Kindie T., Menale K., Tsedeke A., Prasannac BM., Abebe M (2014). Managing vulnerability to drought and enhancing livelihood resilience in sub-Saharan Africa: Technological, institutional and policy options. Weather and Climate Extremes, 3:69-79.

Karugia J., Waithaka M., Freeman A., Prabhu R., Shiferaw B., Gbegbelegbe S., Massawe S., Kyotalimye M., Wanjiku J., Macharia E (2009). Responding to Food Price Crisis in Eastern and Southern Africa: Policy Options for National and Regional Action, Regional Strategic Analysis and Knowledge Support System (ReSAKSS) -Eastern and Central Africa Working Paper, No. 27.

Salami A., Kamara, A.B., Brixiova Z (2010), Smallholder Agriculture in East Africa: Trends, Constraints and Opportunities, Working Papers Series N° 105 African Development Bank, Tunis, Tunisia.

Thomas D (2006). Crop–animal systems in the tropics. In: Thornton P., ed, Trans-Regional Analysis of Crop–Livestock Systems, CABI Publishing, Wallingford.

Dennis G., John D., Jean M.B (2012). Understanding African Farming Systems: Science and policy implications. Prepared for food security in Africa: Bridging research and practice, 29-30 November 2012, Sydney, pp 55.

Hansen J.W., Dilley M., Goddard L., Ebrahimian E., Ericksen P (2004). Climate Variability and the Millennium Development Goal Hunger Target. IRI Technical Report No. 04-04. Pp 23.

Lenné J.M., Thomas D (2006). Integrating crop-livestock research and development in Sub-Saharan Africa: Option, imperative or impossible? Outlook on Agriculture 35(3):167-175.

Giller, K.E, (2001). Nitrogen fixation in tropical cropping systems. Second edition. CABI

Giller, K.E., Tittonell, P., Rufino, M.C., van Wijk, M.T., Zingore, S., Mapfumo, P., Adjei-Nsiah, S., Herrero, M., Chikowo, R., Corbeels, M., Rowe, E.C., Baijukya, F., Mwijage, A., Smith, J., Yeboah, E., van der Burg, W.J., Sanogo, O.M., Misiko, M., de Ridder, N., Karanja, S., Kaizzi, C., K'Ungu, J., Mwale, M., Nwaga, D.,

Pacini, C., Vanlauwe, B., 2011. Communicating complexity: integrated assessment of trade-offs concerning soil fertility management within African farming systems to support innovation and development. Agric. Syst. 104, 191–203.

Josephson, LA., Ricker-Gilbert, J., Florax, J.G.M.R., 2014. How does population density influence agricultural intensification and productivity? Evidence from Ethiopia. Food Policy 48: 142-152.

Mafongoya LP., Kuntashula, E., Sileshi, G (2006). Managing soil fertility and nutrient cycles through fertilizer trees in Southern Africa. In Uphoff, N., Ball, S.A., Palm, C., Fernandes, E., Pretty, J., Herren, H., Sanchez, P., Husson, O., Sanginga, N., Laing, M., Thies, J. Biological approaches to sustainable soil systems. Taylor &Francis, UK 273-289.

Ojiem, J.O., Ridder, N.de., Vanlauwe, B., Giller, K.E., 2006. Socio-ecological niche: a conceptual framework for integration of legumes in smallholder farming systems. Int. J. Agr. Sustain. 4(1), 79-93.

Sanginga. N., (2003). Role of biological nitrogen fixation in legume based cropping systems; a case study of west Africa farming system. Plant Soil 252:25-39

Snapp, A.S., Silim, S.N. (2002). Farmer preference and legume intensification for low nutrient environments. Plant and Soil 245:181-192.

Thornton, KP., Ericksen, PJ., Herrero, M., Challinor, JA., 2014. Climate variability and vulneraability to climate change: a review. Global Chane Biology 20:3313-3328