Coping with Uncertainty: Perspectives on Sustainability of Smallholder Agriculture in sub-Saharan Africa

Case Studies from Kenya

Thesis submitted to Middlesex University for the degree Doctor of Professional Studies by Public Works (Sustainable Agriculture)

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PART I: CONTEXT STATEMENT

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List of Abbreviations

ASDS:	Agricultural Sector Development Strategy
CBA:	Cost Benefit Analysis
DC:	Developing Country
DSS:	Decision Support System
ETI:	Ethical Trading Initiative
FFS:	Farmer Field School
FMC:	Fully mixed concurrent design
FMDS:	Fully mixed concurrent dominant status design
FREG:	The Farmer Research and Extension Group
GAPs:	Good Agricultural Practices
GDP:	Gross Domestic Product
GWC:	Green Water Credits
HPA:	High Agricultural Potential Area
IFOAM:	International Federation of Organic Agriculture Movements
INM:	Integrated Nutrient Management
INMASP:	Integrated nutrient management to attain sustainable productivity increases in East African farming systems
IPM:	Integrated Pest Management
IPM-FFS:	Integrated Pest Management-Farmer Field School
ISFM:	Integrated Soil Fertility Management
KTDA:	Kenya Tea Development Agency
LEIA:	Low External Input Agriculture
LEINUTS:	The potential of low external input and sustainable agriculture to attain productive and sustainable land use in Kenya and Uganda
LPA:	Low-to-medium Agricultural Potential Area
MonQI:	Monitoring for Quality Improvement
MSP:	Multi-stakeholder Process
NAEP:	The National Agricultural Extension Policy
NARS:	The National Agricultural Research System Policy
NASEP:	National Agricultural Sector Extension Policy
NGO:	Non-Governmental Organisation
NUTMON:	Monitoring Nutrient Flows and Economic Performance in Tropical Farming Systems
OFEA:	Towards organic farming in Eastern Africa; Covered Kenya, Uganda, Tanzania and Rwanda (KIOF/ETC Project)
PA:	Participatory Research Approach
PE:	Political Ecology
PLAR:	Participatory Learning and Action Research
PRA:	Participatory Rural Appraisal
PTD:	Participatory Technology Development
QUEFTS:	Quantitative Evaluation of Fertility of Tropical Soils
SLF:	Sustainable Livelihood Framework
SSA:	sub-Saharan Africa
Sust. Tea:	Sustainable Tea Project
TRFK:	Tea Research Foundation of Kenya

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Abstract

Agricultural sustainability of smallholder farms in the tropics has rarely been examined in an integrated manner by addressing simultaneously ecological, social and economic dimensions and exploring its spatial and temporal characteristics. In this submission I have prepared a Context Statement (Part I) that provides a background to my submitted body of works on assessment of agricultural sustainability of smallholder farms in Kenya. In the Context Statement I have positioned myself and my body of works and its impacts, critiqued my methodologies and reflected on my epistemology, brought out overarching messages on sustainability of smallholder farms and examined my research journey and contributions to academic knowledge and to professional practice.

I position my public works within an inclusive ontological realism and epistemological pluralism that informed my use of mixed-methods research. I used (i) decision support systems and models (NUTMON, MonQI and QUEFTS), (ii) participatory learning and interdisciplinary research methodologies (on-farm comparative participatory research, PTD, Farmer Field Schools), and (iii) qualitative perceptions of farmers and researchers to investigate sustainability of smallholder farms. The smallholder farms in the low-to-medium agricultural potential areas were moving in the direction of unsustainability with performance of major indictors related to soil quality, crop productivity and socio-economics below threshold values. This was in direct contrast to the situation in high agricultural potential areas.

The collaborative and interdisciplinary research partnerships within which this body of works was prepared was productive with co-authored papers standing at 98.5% of the total number of papers and the average number of citations per paper by other researchers was 5. My research and the body of works presented together with this context statement created a positive impact on farmers' attitudes, beliefs and behavior regarding sustainability of their farms. Smallholders adopted good agricultural practices and "new" technologies and improved their livelihoods. My reflections on the submitted body of works have further shown that it contributed to knowledge and practice through bridging knowledge gaps on sustainability of organic farming systems, developing new methodologies or adapting current ones to give new meaning in the areas of participatory technology development, communication between "hard sciences" and "soft sciences" on soil quality, farmer learning for sustainability on integrated nutrient management and smallholder tea production, and in the use of decision support systems and models to assess sustainability of smallholder agriculture in an integrated manner.

In the Context Statement I have also reflected on my research journey and painted a picture of the impacts of this doctoral pathway on my research practice and future direction. This doctoral pathway provided the opportunity to blend an academic research doctoral model with my professional research practice resulting in a submission equivalent to PhD by thesis. Through it I have re-discovered myself as a research scientist, a flexible autonomous learner, framed my research experiences as forms of personal, professional and academic growth and created linkages with my career interests and opportunities for improving frontiers of my research practice in the future.

STRUCTURE OF THE CONTEXT STATEMENT

The Context Statement forms Part I of this submission while Part II is the body of works (evidence of achievement).
The Context Statement is divided into the following chapters:

Chapter 1 positions myself and my works; explores the formative influences on the direction of my career and why and how I have done the things I have done.
Chapter 2 gives a background to the body of works, the objectives of the works and the purpose of carrying out this critical engagement with them; gives the rationale for their selection; identifies key knowledge gaps and sub-themes; defines a conceptual model on which the critique was based and clarifies the limitations of the works as well as proposals for future projects and directions.
Chapter 3 describes the political and socio-economic environment characterising the period during which the works took place; the impacts of changing agricultural policies in Kenya and their bearing on this study and on agricultural sustainability.
Chapter 4 analyses the submitted publications in relation to my ontological and epistemological position and a critique of the methodology and research methods used
Chapter 5 explores potentials, impacts and limitations of collaborative interdisciplinary research partnership and leadership
Chapter 6 critiques the outcomes and impacts of the body of works on community of practice and on the research and on development world.
Chapter 7 follows the threads through the public works to synthesise and reflect on emerging messages on agricultural sustainability over the time span in which these works were compiled. It also makes linkages to emerging thinking in agricultural systems and sustainability.
Chapter 8 describes the contribution of these works to knowledge and to practice in the field of agricultural sustainability.
Chapter 9 brings together the key themes which have emerged and the overarching findings and conclusions and presents my reflections on this doctoral pathway, its impact on my practice and my thinking and implications for my future research practice.

CHAPTER 1: POSITIONING MYSELF AND MY WORK: FORMATIVE INFLUENCES

The greatest influences during my formative years which have endured and which have had impact on my decision making and career path are deeply cultural. My personal and professional identities were formed by where I was born, the challenges of life there, by the mixture of tradition and progress, by Christianity and education and by inspiring family members and teachers.

The area around Lake Victoria, Kenya, is today inhabited by River-Lake Nilotes who migrated from South Sudan through Uganda and into Kenya and Tanzania between 1500 and 1800 AD. My ancestors were among these who settled around Lake Victoria in Kenya while other River Lake Nilotes settled in parts of Uganda and a few in Ethiopia (*Anuak*) and others in Tanzania.

The River-Lake Nilotes' migration to Kenya took place in sporadic phases. It is estimated that my ancestors, from southern Sudan, passed through Uganda and settled in Kenya five centuries ago. The dominant occupation of my ancestors in the region surrounding Lake Victoria was mainly fishing in the waters of the Lake and in the rivers that feed the Lake. This was augmented by small scale subsistence mixed-farming which included the growing of traditional crops and raising of indigenous livestock. Crop farming was practised under shifting cultivation methods until the population burgeoned, especially in the second half of 20th Century, forcing my grandparents to abandon shifting cultivation for a more sedentary cultivation.

Another consequence of the population increase was the move away from clan ownership of land, and control and access rights, to individual land ownership, though the two systems of granting access to land are still practised; the latter, however, is becoming more common. The River-Lake Nilotes, although they still practise fresh water fishing in the areas around the Lake, are increasingly playing a large role in urban-based economies in Kenya while still maintaining strong ties to their ancestral homes and to the rural land parcels. In this, my ancestors and grandparents shared a common cultural value with many other Kenyan communities, where arable land is at the heart of existence and dependency on it for our survival and development is recognised. Thus, it is not uncommon to learn from River-Lake Nilotes and some other

Kenyan communities living in urban areas who regard their homes as being in the rural areas (*nyalgunga*) irrespective of the number of years they have lived in urban areas.

I was born in the rural areas surrounding Lake Victoria, Kenya in 1968 and enjoy the serene lake environment where small-scale farming is practised. My father was a small scale farmer but with artisan skills and he combined them for a living. He was employed as an artisan in the urban City of Kampala in Uganda in the 1960s and later moved to Nairobi, Kenya in the 1970s. Although employed in the urban areas, he returned frequently to the rural home where my mother and the rest of my siblings lived and took care of the family land. We would from time to time visit my father in the urban centre, but return to our rural homes where our lives were interwoven with farming practices. My parents introduced us to rural farming at a very young age. This early training in land care and agricultural practices not only inspired me and my siblings but also gave us practical skills that we continue to use today. All my family members and siblings still have strong ties to the land and to mixed small scale farming.

The seeds of the professional identity

I was fortunate to attend a well-regarded kindergarten run by the Catholic Mission with a strong educational and ethical philosophy. These early school years provided me with a positive experience complemented by having a close family proud of their identities and their skills in surviving and developing. In those days attending kindergarten was not common in my rural village due to inadequate kindergartens, parents' perceptions that it was not necessary and educational policies that did not integrate early childhood education into the mainstream education system leaving early childhood education to religious groups (rural settings) and to private entities (in urban and peri-urban centres).

My early childhood education ignites in me fond memories but it started with fear and anxiety: the fear of meeting children and people I had never met in my life and anxiety about the teachers whose words were like those of the gods, with finality that none dared break. But I derived the values and practices towards self and others that I cherish to this day: relating and appreciating other people - the young, the old and people of the same age; the value of optimism and having faith in God and that tomorrow would always be better than today. I took two years in pre-unit instead of one for reasons revealed to me only in adulthood. In those days children were not allowed to go to Primary School, unless they “could use their right hand to touch their left ear” as a sign that they were mature enough for Primary school. I was not able to meet this condition until 1975. The requirement was an inherited tradition from educationists in pre-independence days and has since changed. Life in the pre-unit was interesting: recitations of alphabets which one did not even know how to write, being introduced into rural folklores and/or being taught how to sing lyrics which one could not write down among other lessons. The pre-unit years privileged oral tradition which helped us to develop a good memory.

I undertook my basic education (1975-1982) at a school, about 2 km away from our rural home. Writing this now evokes memories. I would go to school barefoot every day walking the 4 km round trip. It was in this period that I was introduced to small scale agriculture by helping my family on the farm over weekends and daily before going to school. Throughout my primary school life I lived with my paternal grandmother, a peasant farmer. She introduced me to the life and culture of the Luo people and more so the Christian faith, and inspired me to continue with education. Despite her advanced age she enrolled in adult education classes to be able to read and write especially to read her bible.

My primary education gave me a love for reading, a curiosity and a thirst for knowledge. Not being privileged to attend a primary school with better facilities did not stop me from exploring the world of science. I took it upon myself to read diverse books on science whenever I could lay my hands on them as my school did not have a library even for books on the school syllabus. However, I borrowed from other children at other schools especially during the school holidays. The spirit of curiosity and hunger for knowledge invoked in me a lifelong passion for how the scientific world works. The seeds of leadership were also sown in me at this early stage. I was a class representative in almost all the primary school classes that I attended and sometimes moderated class debate sessions. My memorable moments in school were when I was awarded a trophy twice for the best disciplined pupil. I believe that it is this self-discipline and commitment to succeed that contributed to my advancement in life and in breaking the school exam record, a record that remained until the education system was changed.

Developing ideas of a future

My high school education took place in, Ukwala High and later Sawagongo High both in Siaya district, Nyanza Province of Kenya. The high schools had limited facilities and fewer teachers compared to other high rated schools nationwide. There were no remedial or "catch-up" classes or holiday tuition then. However, the drive to succeed and to excel was in me. Together with other students, we formed "class clubs" through which we could share notes and debate our understanding of different topical issues in the syllabus and where there were no teachers, these "class clubs" laid the foundations upon which our preparation for national exams were based and upon which we could collectively revise. I was fortunate to be elected head of student-librarians which gave me access to titles available in the library and to ease access for other students.

During my school days, I was regularly challenged by my teachers with the same question: "What do you want to be when you grow up?" I was all jumbled up in my answers, sometimes answering perhaps a doctor, perhaps an agricultural officer but inside me I was not jumbled up. I knew I wanted to do something that was definitely a "science-based" profession. I was considered bright and was encouraged to choose a profession in health sciences and/or agriculture. I eventually decided to pursue a career that would involve mixed farming systems and contribute to improving and sustaining such systems into the future. I enrolled into the science stream in high school and battled with mathematics, biology, chemistry, physics and geography to meet the requirements of national examinations that would gain me entry into the profession of agriculturalist.

In 1989, prior to joining a public university, I was obliged to enroll in the National Youth Service (NYS). Since 1985 the Government of Kenya had made it compulsory for all students joining public universities to undergo a three month pre-university NYS[1] training course mandated to train young citizens to serve the nation, employ its members in tasks of national importance and/or otherwise offer service to the nation. Courses took the form of the basic drill followed by professional courses in various fields. This programme was initiated to make university students disciplined and thus minimise incessant student riots. It was shelved in 1990 when it became too expensive to run[2]. While devoting resources to such a programme had been controversial, the skills acquired through it have served me well as they exposed me to real life challenges and survival skills which enhanced my self-dependence and patriotism, gave me a fresh look at national development issues and strategies and affirmed in me the virtue of self-discipline and service to the society.

Learning the practical application of theory

I started at Egerton University, Kenya in 1990 and graduated with a BSc. in Horticulture. Besides the study of horticultural topics, the course was competitive and unexpectedly blended with other disciplines including animal science, food technology, soil fertility and agronomy, agricultural economics, environmental sciences, statistics and mathematical sciences. I resented the blend of subjects at first and almost withdrew from the course in the first year. However, my commitment to eventually get involved in developing soil fertility management practices and sustainable mixed farming systems was ignited afresh and I soldiered on. I remembered the old dirge: "honouring our commitments can make the difference between achieving what's most important to us and feeling disappointed and defeated for life". These early beginnings sowed in me the seed of "integration". I began to consider farming practices to be integrated and anchored in environment (ecology), economics and in social dimensions that contribute to the same whole.

I see now that my strongly self-motivated approach to learning complemented by my group-oriented approach played a major role in helping me succeed on the course.

[1] NYS: National Youth Service; gives vocational training to young citizens, instil patriotism and morals, empower youths to help safeguard the country, train them in tasks of national importance, including offering service to the nation (in national reconstruction programmes, disaster response etc.).

[2] In July 2013, the Kenyan Parliament (Senate) debated a bill and passed a law to re-introduce the NYS conscription for high school graduates.

The ability to teach myself something new from reading and trying things on my own with the flexibility to benefit from group work and interact and learn from others have been core to all my work and research practices. I was privileged to get a hands-on practical secondment prior to graduation at Kitale Prison Farm. Similarly, I was given an opportunity to be part of a research team that solicited smallholders' views on agricultural practices around the university. The practical secondment built my confidence and further equipped me with the necessary skills required for work in my chosen profession. Being part of a collegiate research team also opened my eyes to the opportunities for being a researcher. Today my interests and professional discourse can be traced to these small beginnings. I discuss this fully later on.

In 1993 I took employment as a research assistant with the Kenya Institute of Organic Farming where I worked for nine years conducting participatory research on the potentials and limitations of organic farming practices and soil fertility management among smallholder farmers. I later became the research and outreach coordinator leading a team of other researchers in the department, a position which also gave me access to a number of short term courses on organic farming, agricultural sustainability, ecological agriculture, participatory research and soil fertility management. Some of these attracted international participation, and contributed to my view on how to conduct participatory and multidisciplinary research. The impacts of the research findings and the challenges met during this period motivated me to seek further education on agricultural sustainability. In 2003, I enrolled for a post graduate course on Sustainable Agriculture and Rural Development in the University of Free State, South Africa (UoVs).

My dream to pursue postgraduate studies on sustainable agriculture and rural development was made a reality while working with a regional consultancy firm, ETC East Africa Ltd. The two years that I undertook the study were among the most fulfilling years of my life. It informed my current perspectives on agricultural sustainability, multidisciplinary and participatory research and the integration of disciplines as pre-requisite for attaining sustainability. These factors and perspectives have contributed to my modern day professional career of working at the interface between the biophysical (environmental), socio-economic and institutional and policy environment to advance the course of sustainable agriculture and soil fertility management in smallholder farms through adoption of holistic approaches.

Career and Professional Development: pulling threads together and making them work

Personal commitment, identification of gaps and working towards bridging them have been the motivational factors in my career, especially on issues of integrated assessments that combine economic, ecological and social goals to attain sustainability. Research on sustainable farming systems is limited in the Kenyan context and the few studies that exist are anecdotal in nature and have been carried out in ways, places and with means that cannot be easily implemented afterwards by farmers. Long term experiments are limited and as is participatory research on agricultural sustainability. By responding to these gaps, my field experience and past research have been institutive and received well among development practitioners and conventional researchers. This has encouraged me in on-farm participatory research, but also in sharing the research outputs with the development and scientific community. Participatory research describes a process that is based on dialogue between farmers and researchers in order to develop improved technologies that are practical, effective, profitable, and that can address identified agricultural production constraints.

My previous and present research efforts have been anchored in multidisciplinary and multi-institutional teams. This has made the outputs more easily acceptable in the scientific community and offered a platform for dissemination. Furthermore my involvement in NUTNET[3] a network on soil fertility management that brought together various researchers on soil fertility management, socio-economic context and policy processes in which soil fertility is managed, helped to advance my research capability through sharing research methodologies and conducting nutrient budget analysis at farm and at field level.

[3] NUTNET is a network of 15 organisations from six African countries and two European countries with the aim of improving soil fertility in Africa.

Rather than keeping research results within the development and scientific community in archives and journal papers, I had a strong conviction that research results should impact on smallholders' lives. This was more so given the fact that the smallholders were involved in major parts of my research process. I initiated "farmer-feedback workshops" that brought all participating farmers, researchers and development workers to share experiences, evaluate field trials, participate in district policy workshops and share results on what practices they had adopted as a result of being involved in the research work. This proved valuable and encouraging to farmers and researchers. The implication of such interaction was that the biophysical (environmental), socio-economic, institutional and policy factors that determine soil fertility management and agricultural sustainability were discussed on a common platform and in a holistic manner. The enthusiasm from such workshops encouraged me to organise many such platforms alongside media, conferences and formal research publications.

What helped me in dissemination to a variety of stakeholders to change the way farming is practised is that I love writing. I dedicated time to writing every month and now with hindsight, it appears that the more one dedicates time to writing, the more one perfects the art, especially when the purpose and motivation are clear. My first co-authored article to be published in an International Journal was in 1997 (Appendix 5). I still continue writing to date, publishing in different media[4], and presenting research results at various conferences and workshops[5] (Appendices 4 and 5)[6].

The following public works tell the story of the rest of my career to date weaved in the various learnings that emerged for me not only at the time of the works but renewed and developed as part of the process of my critical engagement with them during this doctoral programme.

[4] Published materials include research reports, journal articles, book chapters etc.

[5] Examples of conference presentations can be found at: http://www.greenwatercredits.net/documents

[6]Themes include organic farming and sustainable agriculture (e.g. 1993-2001); soil fertility management and farmer learning for agricultural sustainability (2002-to-date)

CHAPTER 2: INTRODUCTION TO THE PUBLIC WORKS

2.1. Background

This statement along with the body of works (page 10) I am presenting form a unified account of how the knowledge for this Doctoral award was produced and the contribution it has made to the community of practice, to the broader discipline of soil fertility management and agricultural sustainability research practice and to me as a researcher and practitioner. It weaves together common threads and themes that run across the entire body of works to create a coherent whole. The body of works is based on research undertaken to assess agricultural sustainability of smallholder farming systems with case studies from Kenya. The research results were published in peer reviewed journals and intermediate academic and scientific reports. On-going debates on sustainability of smallholder farms and food production in sub-Saharan Africa are presented in Appendix 1.

Focus of the critique of the works

Specifically this context statement and the submissions made have the following objectives:

- To position myself as a researcher and how my values, practice and experiences have informed and driven my research practice over the years
- To critique the methodology, reflect on epistemology and position the body of works in relation to what is happening locally, in other developing regions and also in the international scene
- To explore potential, impacts and limitations of collaborative interdisciplinary research partnership and leadership within which this body of public works was produced.
- To critique the outcomes and impacts of the body of works on communities of practice in research and development.
- To analyse, synthesise and reflect on emerging perspectives on agricultural sustainability in relation to the body of works using an integrated assessment framework

- To explore the contribution of this body of works to knowledge and to professional practice
- To critically reflect on the impact of this critical engagement for my current and future practice and direction

My personal investment

I have lived to see the stresses and challenges that smallholders' face daily in their quest to improve food production. My personal drive and intrinsic interest to address this challenge of improving the sustainability of smallholder farms and do something that would make a difference to peoples' lives led me to purposefully choose to conduct this research guided by my belief and passion that overcoming smallholders' challenges would eventually make life meaningful. This was my inspiration and gave me the energy to invest my personal time in this research, beyond the bounds of that of my fellow researcher peers. Furthermore, I have observed that smallholders' full participation in research is often overlooked by researchers and development practitioners on the assumption that they are ignorant and are better off adopting technologies that have been developed by "researchers" or those that have been disseminated to them through the conventional extension system. My contrary position, that smallholders living in resource-poor regions that are complex, diverse and prone to risks need to be fully involved in research processes to make a difference, led me to conduct development oriented and participatory research in which the smallholders views, constraints and perceptions are fully integrated into the research process. This research was further guided by my belief that the vulnerable poor and voiceless smallholders need to be included in the research to capture their creativity, knowledge of nature and perceptions, to conserve land and other agricultural resources and give them opportunity to contribute to their own development pathway. It was with some delight that during the course of this doctoral programme that I came across Paulo Freire's "pedagogy of the oppressed" in which strategies to promote the voice of the marginalised are forged *with* them and not *for* them; and where embracing freedom and inclusion involves adopting new strategies for change and proactive participation in development and liberation; and where through education, the marginalised can deal creatively with their environment and transform their world

(Freire, 2005). I had arrived at such thinking as he must have, through the experience of hardship.

Collaboration with others to improve practice knowledge

The body of works included here has its roots in field surveys, on-farm participatory and action research and farmer learning on agricultural sustainability. This involvement of the farmers in the research process had a significant impact on their approaches to their land and to their farming practices even before any results were distilled and distributed to them. The results as published in journals were of more relevance to other stakeholders such as funders, policy makers, and other researchers in this field of sustainability.

I adopted a participatory action research process in these studies where research planning, field work, communication of final results and use of the results to initiate change were done with full involvement of research participants and partners. This provided an opportunity for the convergence between science and practice (Bergold and Thomas, 2012). This process of conducting research has enriched the body of works presented here by capturing both quantitative and qualitative data, including researchers and farmers' disclosures of personal views, experiences and opinions. The results were generated in the lived environment of farmers thus their application tended to fit within the smallholders socio-economic circumstances and biophysical environment and since farmers participated in all the stages of the research, they could easily attach a meaning to the research results. Furthermore, field research enabled me to interact with farmers in ways that could not have been possible were this research to have been carried out on station. It enabled me to factor into the research process, farmers indigenous knowledge, circumstances and multiple farming objectives as well as to appreciate that farmers live in both technical and social worlds informed by traditions, experiences and emerging technologies. My engagement with farmers on the ground had a significant impact on me as a researcher in the field and the way I adapted my research approaches as discussed in later sections of this context statement.

A dialogue with existing knowledge

I enriched the results of the field studies with complementary desktop studies to interpret the results in light of previous and current related research resulting in various journal publications. However, methodologies and materials for dissemination of research results at farm level were kept simple using visualisation methods-graphics, posters, pictorials, booklets (Examples in Appendix 2; publications 9, 10 and 14).

2.2. Positioning the outcomes of the research

In the body of works, I challenge the paradigm that an agricultural system can be evaluated as partially or conditionally sustainable (Smyth and Dumanski, 1993; Hartemink, 2003) and have adopted a holistic assessment approach integrating biophysical (soils, climate and water), socio-economic (farm financial performance, farmer perceptions, poverty etc.), and institutional and policy factors (physical infrastructure, input-output markets) (Scholes et al. 1994; CGIAR, 2002; Rosegrant *et al*., 2005; Aid, 2011). By adopting this approach, I have attempted to advance the current knowledge base in Kenya and other developing countries where integrated studies of this nature are limited, tend to be anecdotal and confined to agronomic evaluations and mainstream economics without cognisance of ecological costs of production and required integrated assessments (Izac, 1997; De Jager, Nandwa and Okoth, 1998; Tietenberg, 2003).The integrated assessments have been partially aided by two decision support systems (DSS): (a) NUTMON-monitoring nutrient flows and economic performance of tropical farming systems (Vlaming *et al*., 2001a; Vlaming *et al*., 2001b); and (b) QUEFTS-Quantitative Evaluation of the Fertility of Tropical Soils (Janssen et al., 1990).

I have included soil quality and fertility in this integrated assessment as soil fertility decline is a biophysical root cause of declining yields in sub-Saharan Africa (SSA) and soil quality determines whether soils will function and sustain biological productivity, environmental quality, and promote plant and animal health (Smaling, 1993; Doran and Parkin, 1996; Scoones and Toulmin, 1999). I have challenged the conventional wisdom that all soil parameters are significant in sustainability assessment and instead have determined site specific minimum dataset of soil quality parameters (Guilin *et al*., 2007; Onduru *et al.,* 2008a). Similarly, I have assessed the status of soil quality and fertility using nutrient balance approach at lower spatial scales (farm and field level) to inform and challenge the on-going debate on seminal studies on soil fertility decline and land degradation conducted at national and continental levels (Mortimore and Harris, 2005).

I have taken into account spatial and temporal dimensions of sustainability as the spatial structure observed in a system relates to the spatial and temporal scale over which measurements have been taken (Fresco and Kroonenberg, 1992; Hiebeler and Michaud, 2012). Similarly ecological and economic aspects of sustainability have spatial and temporal dimensions including distribution of costs and benefits (Jordan and Fortin, 2002). I have assessed spatial and temporal dimensions of agricultural sustainability using soil quality indicators, nutrient monitoring model (Onduru *et al*., 2007c.; Onduru and Du Preez, 2008c), QUEFTS model (Janssen *et al*., 1990), crop yields and rainfall, and financial efficiency of soil and water conservation practices at different time scales and discount rates to estimate intragenerational and intergenerational equity aspects of sustainability (Onduru *et al*., 2013).

Furthermore, I have explored the claims that alternative farming systems such as organic and low external input systems are sustainable (De Jager *et al*., 2001) and contributed to methodologies of organic farming system assessments as the few studies that exist in SSA tend to lack methodological rigour (Werf van der *et al*. 1997). I have assessed the sustainability of organic and low external input farming systems through (i) on-farm comparative agro-economic assessments of organic farming practices and their conventional equivalents; and (ii) by using farming system approach and multi-dimensional indicators, namely nutrient balances and farm financial performance and productivity (Onduru *et al*., 2005). I have further presented methodological experiences and lessons leant in the assessments (Werf van der *et al*., 1997).

In the body of works I have explored the application of farmer field schools (FFS) to enhance learning and experimentation on integrated nutrient management (INM) (Onduru *et al*., 2008b; Onduru *et al*., 2006), and in enhancing sustainability of smallholder tea systems and annual-crop based smallholder farms (Onduru *et al*., 2012a). Although FFS[7] have been proposed as a participatory learning process that builds farmers knowledge, skills and capacity to make farming systems sustainable (Deugd et al 1998), there have been limited efforts in documenting FFS experiences, especially in enhancing farming system sustainability by stimulating farmer learning on INM[8] and good agricultural practices

Through this critique I intend to bridge existing knowledge gaps in the use of farmers' local knowledge and perceptions in agricultural sustainability assessment (Fairhead, 1992; Paytona *et al*., 2003; Saidou *et al*., 2004; Handayani and Prawito, 2010); address inadequate understanding on how farmers local knowledge can be integrated with scientific knowledge to assess agricultural sustainability (Lima *et al*., 2011; Davis and Wagner, 2003; Eshuis and Stuiver, 2005); and challenge current perceptions held on the severity, extent and impact of land degradation as a threat to agricultural sustainability (Koning and Smaling, 2003). I further explore whether farmers indigenous knowledge and perceptions on soils and soil fertility are congruent with scientific indices, appraise how indigenous knowledge on soils can contribute to agricultural sustainability assessment and propose a methodology of communication between farmers and scientists on soils (Onduru *et al*., 1998). I also present data and farm level perspectives to question generalisations of seminal level studies on land degradation and agricultural sustainability (Muchena *et al*., 2005).

This body of works was produced as collaborative and interdisciplinary research in which a collaborative leadership style was adopted. I describe the features of this collaborative leadership, processes of engagement and emerging lessons that facilitated the research impacts in addition to distilling lessons leant from the interdisciplinary nature of the collaboration. I further analyse leadership roles within the interdisciplinary collaboration using social network analysis based on data from co-authored publications using a framework provided by Gray (2008).

[7] FFS: Farmer Field School
[8] INM: Integrated Nutrient Management

2.3. The Body of Public Works

2.3.1. Overview of submitted body of works

Background to the body of works

My submitted publications are drawn from research work conducted over the period 1993-2012 (Table 1). The earlier work is included to show the developmental links without which the later works cannot be appropriately contextualised in terms of the evolution of knowledge through learning from practice. The first publication was made in 1997 after three years of on-farm participatory research work and the last publication included with this publication was published in 2013. I have assigned sequential numbers to these publications for ease of reference in the subsequent paragraphs and chapters of this context statement (see Table 2). The research environment, that involves farmers, has greatly changed over the last 20 years from on-farm research to participatory and action oriented research, multidisciplinary and multi-institutional research and to farmer learning approaches that seek to engage farmers in a process of self-reflection and learning on agro-ecological principles and practices. This research and body of works have contributed to the development of this paradigm shift in Kenya at a time when most research activities were on-station (basic research) or researcher managed. I was part of this change that led to early adoption of inclusive participatory research approaches and gave voice to the oppressed. The research paradigm adopted in this body of works recognises that multi-faceted farming system constraints require synergistic expertise from different disciplines and a high level of resource inputs than cannot be provided under mono-disciplinary and single institutional approaches; and that full participation of farmers in the research process strengthens the process and outcomes of research.

The research environment has also changed with regards to salient questions being asked about (i) the necessity to increase food production and arrest the degradation of production resources on which agriculture depends (ii) sustainability of farming systems (high and low external input systems), including what has been perceived as sustainable or organic farming systems; and (iii) the contribution of smallholder farmers in feeding developing World. The submitted publications (consigned in part III) address these issues and more so the detailed questions raised in Section 1.3.1 of this Context Statement.

Table 1: Research projects undertaken between 1993 and 2012

Project	Full title
OFEA: 1994-1996	Towards organic farming in Eastern Africa; Covered Kenya, Uganda, Tanzania and Rwanda (KIOF/ETC Project)
LEINUTS: 1997-1999	The potential of low external input and sustainable agriculture to attain productive and sustainable land use in Kenya and Uganda; covered Kenya and Uganda
INMASP: 2001-2005	Integrated nutrient management to attain sustainable productivity increases in East African farming systems (covered Kenya, Uganda and Ethiopia)
Sust. Tea: 2006-2008;2009-2012	Sustainable Tea Project; covered Kenya
GWC: 2011	Green Water Credits Feasibility Studies; covered Kenya

The publications taken as a whole make an assessment of sustainability of smallholder farms in tropical developing countries with cases from Kenya. The publications have been selected to address the following four interrelated sub-themes (Table 2):

- Spatial and temporal aspects of agricultural sustainability (sub-theme 1)
- Sustainability of organic and low external input agricultural systems (sub-theme 2)
- Farmer learning for agricultural sustainability (sub-theme 3)
- Knowledge and perceptions on agricultural sustainability (sub-theme 4)

Table 2: Overview of submitted publications

Publication		Project	
No.	**Description**	**Acronym**	**Period**
Sub-theme 1: Spatial and temporal aspects of agricultural sustainability			
1	**Onduru, D.D**., Du Preez, C.C., De Jager, A and Muya, E.M., 2008a.Soil quality and agricultural sustainability of dryland tropical farming systems: A case study in Mbeere District, Eastern Kenya. *Journal of Crop Improvement* 21 (1): 79-100; DOI:10.1300/J411v21n01_06	INMASP	2001-2005
2	**Onduru, D.D** and C. C. Du Preez. 2007a. Spatial and temporal dimensions of agricultural sustainability in semi-arid tropics: A case study in Mbeere District, Eastern Kenya. *Tropical Science* 47 (3):134-148; DOI: 10.1002/ts.207	INMASP	2001-2005
3	**Onduru, D.D.** and Du Preez, C.C., 2007b.Ecological and Agro-economic study of small farms in sub-Saharan Africa. *Agronomy for Sustainable Development* 27: 197-208.DOI: 10.1051/agro: 2007003.	INMASP	2001-2005
4	**Onduru, D.D.,** De Jager, A., Muchena, F.N., Gachimbi, L. and Gachini, G.N., 2007c.Socio-economic factors, soil fertility management and cropping practices in mixed farming systems of sub-Saharan Africa: A study in Kiambu, Central highlands of Kenya. *International Journal of Agricultural Research* 2 (5): 426-439.	INMASP	2001-2005
5	**Onduru, D.D**., Muchena, F.N., Njuguna, E., Kauffman, S. 2013. Financial Efficiency and Intergenerational Equity of Soil and Water Conservation Measures in Kenya. *Greener Journal of Geology and Earth Sciences 1(2): 43-62.*	GWC	2011
Sub-theme 2: Analysis of sustainability of organic and low external input agricultural systems			
6	Werf van der, E., Kariuki, J.and **Onduru, D.D.,** 1997.Methodological Issues in Comparative Agro-Economic On-Farm Research Assessments of Organic versus conventional Farming Techniques. *Biological Agriculture and Horticulture* 14: 53-69.	OFEA	1994-1996
7	**Onduru, D.D.,** Diop, J.M., Werf, E. Van der and De Jager, A., 2002.Participatory On-farm comparative assessment of organic and conventional farmers practices in Kenya. *Biological Agriculture and Horticulture* 19: 295-314	OFEA	1994-1996
8	**Onduru, D.D.,** De Jager, A. and Gachini, G.N., 2005.The hidden costs of soil mining to agricultural sustainability in developing countries: A case study of Machakos District, Eastern Kenya. *International Journal of Agricultural Sustainability* 3 (3): 167-176	LEINUTS	1997-1999
Sub-theme 3: Farmer learning for agricultural sustainability			

9	**Onduru, D.D**., C.C. du Preez, F.N. Muchena, L.N. Gachimbi, A. de Jager and G.N. Gachini., 2008b. Exploring options for integrated nutrient management in semi-arid tropics using farmer field schools: a case study in Mbeere District, Eastern Kenya. *International Journal of Agricultural Sustainability 6 (3): 208-228;* Doi:10.3763/ijas.2008.0267	INMASP	2001-2005
10	**Onduru, D.D**., De Jager, A., Wouters, B., Muchena, F.N., Gachimbi, L. and Gachini, G.N., 2006.Improving Soil Fertility and Farm Productivity under Intensive Crop-Dairy Smallholdings: Experiences from Farmer Field Schools in the Highlands of Kiambu District, Central Kenya. *Middle East Journal of Scientific Research* 1 (1): 31-49	INMASP	2001-2005
11	**Onduru,** D.D., De Jager, A. and Van den Bosch, R., 2012a.Sustainability of smallholder tea production in developing countries: Learning Experiences from Farmer Field Schools in Kenya *International Journal of Development and Sustainability* 1(3): 714-742	Sust. Tea	2006-2008
12	**Onduru, D**., De Jager, A., Gachini, G., Diop, J-M., 2001. Exploring new pathways for innovative soil fertility management in Kenya. Managing Africa's Soils No.25. IIED, UK	LEINUTS	1997-1999
Sub-theme 4: Analysis of knowledge and perceptions on agricultural sustainability			
13	**Onduru, D.D**. and Du Preez, C.C., 2008c. Farmers' knowledge and perceptions in assessing tropical dryland agricultural sustainability: Experiences from Mbeere, District, Eastern Kenya. *The International Journal of Sustainable Development and World Ecology 15 (2): 145-152.*	INMASP	2001-2005
14	**Onduru, D.D**., Gachini, G.N. and Nandwa, S.M. 1998. Experiences in Participatory Diagnosis of Soil nutrient management in Kenya. Managing Africa's Soils No. 3. IIED, UK.	LEINUTS	1997-1999
15	Muchena, F.N., **D.D. Onduru** and A. de Jager., 2005.Turning the tides of soil degradation in Africa: capturing the reality and exploring opportunities. *Land Use Policy* 22: 23-31. [doi: 10.1016/j.landusepol.2003.07.001]	INMASP	2001-2005

Rationale for selecting the publications

This context statement interlinks the publications presented in Table 2 thus forming a coherent theme on the status of sustainability of smallholder agriculture.

Five publications, which together address spatial and temporal aspects of agricultural sustainability of smallholders in contrasting agro-climatic zones , namely, publications 1, 2, 3, 4 and 5, (Table 2, sub-theme 1).The five publications explore the impacts of households' soil fertility management strategies on soil quality and agricultural sustainability, both in spatially and temporal terms. Poor soil management is expected to result in declining soil quality, over time, with a negative bearing on agricultural sustainability. Since the concept of ecological and agro-economic sustainability has different meanings at different spatial scales, these five publications contextualise study results to the study location and to similar agro-climatic settings (Zinck and Farshad, 1995). Time series data are used to explore the temporal dimension of agricultural sustainability, which is more useful in determining resilience and stability of agricultural systems than a one-point-in-time observation (Lütteken and Hagedorn, 1999; Herdt and Steiner, 1995).

Sustainability of organic and low external input farming systems are assessed in diverse agroecological zones to investigate opportunities and limitations of various farming systems in attaining agricultural sustainability in *three inter-related publications*, namely, publications 6, 7 and 8 (Table 2, sub-theme 2). Claims that agricultural development and rural poverty reduction can be based on an expansion of the green revolution and biotechnology in Kenya, and elsewhere in SSA, are often met with the argument that pesticides and chemicals are responsible for environmental problems, soil degradation and health risks; while biotechnology is associated with potential risks (Tripp, 2006; FAO, 2002). This has precipitated the search for alternative farming approaches perceived to be sustainable and environmentally friendly. Such farming approaches, for example organic farming, are characterised by LEIA[9] technologies that can be promoted through learning techniques for building farmers human and social capital. The three publications under this sub-theme seek to understand the potential contribution of organic farming and LEIA to agricultural sustainability using comparative farming systems methodology (relative assessment).

[9] LEIA: Low External Input Agriculture

The comparative farming system study is done by assessing organic farming practices/LEIA against their mainstream (conventional) equivalents under smallholder settings. The comparison is based on soil nutrient balances and agro-economic potentials of the studied farming systems. Similarly, the smallholder systems are compared with regards to their performance in low-to-medium and high agricultural potential areas.

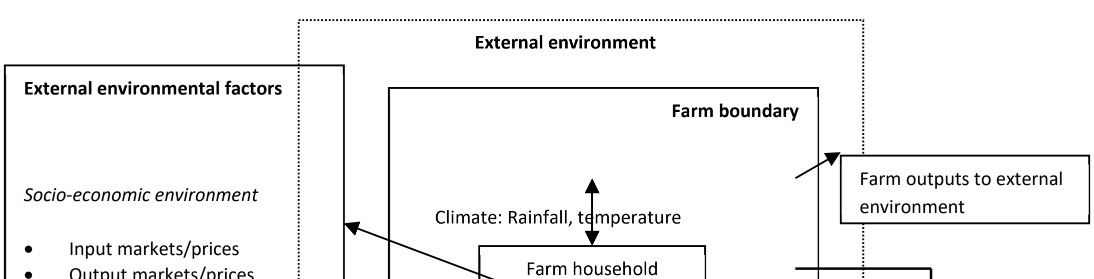
Farmer learning on agricultural sustainability is explored based on *three publications* on social learning in farmer field schools*:* Publications Nos. 9, 10 and 11 (Table 2, sub-theme 3) and one publication that gives cross-cutting view on participatory technology development on soil fertility and agricultural sustainability, publication No. 12. Social learning is a vital part of the process of adjustment in sustainable agriculture and is expected to lead to increased innovation and likelihood that the social processes will persist and that the technologies generated will be adopted into the future (Pretty, 1995). Sustainable agriculture is not an 'innovation' that farmers 'adopt' (Seppänen, 2002). Changing to more sustainable practices involves a new learning pathway leading to new perspectives on technologies, new ways of doing things and integrating experiential learning, reflection and observations (Reijntjes *et al*., 1992; Röling and Van de Fliert, 1994). The approach is flexible and not prescriptive on a set of defined technologies, practices or policies and as conditions and knowledge change, farmers and communities make adjustments to the new farming conditions through a process of social learning (Pretty, 1995). Since sustainable agriculture incorporates the best components of indigenous farmers' knowledge and practices, ecological principles, and conventional and new approaches in science (e.g. systems approach, agroecology etc.), it is often developed through adaptive experimentation and processes of social learning that contribute to enhancing farmer's skills and broader community capacities (Reijntjes *et al*., 1992; Tripp, 2006).

Farmer and scientists' perceptions and knowledge and their contribution to understanding agricultural sustainability is presented in three *Journal articles*: publications 13, 14 and 15 (Table 2, sub-theme 4). These publications together argue that the term sustainability is socially constructed, and thus an integration of farmers' knowledge, extension workers and scientists' knowledge is required to understand the direction of agricultural sustainability and priority constraints and opportunities for making agriculture sustainable(Dormon *et al*., 2004; (Okali *et al.,* 1994). Furthermore, local innovations on coping with adversities that affect agricultural sustainability exist at farm level, but have not been fully understood by conventional science (Saidou *et al*., 2004).

2.3.2 Conceptual model

In this section, I give a brief account of this study's theoretical framework and how the various sub-themes and publications relate to each other. Figure 1 presents the study's conceptual model. Agricultural sustainability is understood as a visionary paradigm resting on three dimensions of ecology, economics and social equity. The three dimensions are integrated and thus are considered together for practical assessment of agricultural sustainability. For practical reasons I have adopted the definition of sustainable agriculture after the American Society of Agronomy to mean "one that, over the long-term, enhances environmental quality and the resource base on which agriculture depends, provides for basic human food and fibre needs, is economically viable, and enhances the quality of life for farmers and society as a whole (Wilson and Tyrchniewicz, 1995).

The different sub-themes of sustainability explored in this context statement are interwoven together in an integrated assessment under a study framework based on farming system theory. I have used the terminologies farming system and agricultural system interchangeably to widen the room for understanding the study framework since these assessments of smallholder farming systems were done at different points in time under changing field perspectives and circumstances. I have conceptualised a smallholder farming system as a functional unit having physical borders with an external environment and an internal environment.



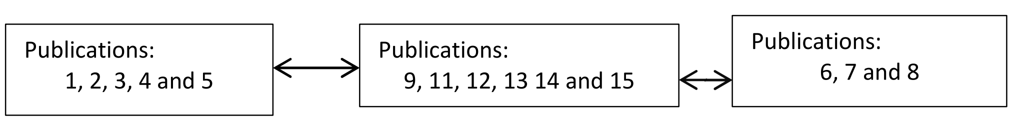


Figure 1: Conceptual Model of this Study

The external environment is the source of purchased inputs and destination of outputs transported outside the physical farm boundary and comprises input and output markets and the policy environment. The internal farm system comprises sub-systems which interact with each other through input and output flows and with other agro-ecological factors in the farm system. The sub-systems include soil, plant, livestock, manure/garbage heap, inter-dependent enterprises and the household and the associated inputs and outputs, and interactions between them and other agro-ecological factors, including the entire complexity of ecological, economic, social and cultural conditions that influence farm productivity and sustainability (Scholes *et al*., 1994). The farm sub-systems also interact with other agro-ecological factors such as rainfall. The household manages the various farm components and depending on the farm management skills available (human capital), the status of the production resources (soils, water, energy etc.) or physical capital, and socio-cultural perspectives (social capital) and farm financial resources (financial capital), the farm can be considered to be moving in the direction of sustainability.

To assess whether the farming systems are progressing towards sustainability, I have analysed farm performance based on the following inter-related determinants (pillars or attributes) of sustainability: productivity, socio-economic viability and conservation and stewardship of production resources (ecological determinants) (Chapter 6 and Appendix 1). These determinants of sustainability collectively contribute to the concept of agricultural sustainability with three dimensions (evaluation areas), namely ecological (biophysical factors), social and economic. Sustainability in this case refers to the ability of agricultural systems to indefinitely provide sufficient food, feed, and fibre at socially acceptable economic and environmental costs (Crosson, 1992).

Since smallholder systems are complex in nature with components operating on different space-time scales, I have used proxy indicators that can measure the effects of farm management changes on the state of the system for each of the three dimensions of sustainability (Fernandes & Woodhouse, 2008). Analyses of indicator and farm performance were done in temporal and spatial dimensions including analyses at plot (activity) and at farm level with the plot being the lowest scale of study. The plot or activity scale was viewed as comprising the soil and plant sub-systems as well as livestock and manure heaps/garbage sub-systems.

The publications here address the three dimensions of sustainability in an integrated manner based on two assessment procedures, viz, absolute assessment procedure and comparative assessment procedure. Absolute assessment is based on investigation of the performance of sustainability indicators and corresponding data derived from a single farming system (Dariush Hayati, 2011). I have used this procedure to determine the direction of agricultural sustainability based on a comparison of indicator values with their threshold values derived from literature or expert knowledge for investigations done in high and low potential areas of Kenya. This forms the basis of assessing agricultural sustainability as enshrined in publications 1 up to 5. Comparative agricultural sustainability procedures are based on comparison of two or more agricultural systems making it possible to conclude that one agricultural system is superior to another in terms of performance. I used this method to compare organic and conventional farming systems, (publications 6, 7 and 8).

In this integrated assessment, I considered both absolute and comparative assessments to be complementary as each procedure brings out different dimensions of agricultural sustainability that contributes to making the overall decision on whether smallholder farming systems are sustainable. In sub-theme three (publications 9-12), I have combined absolute assessment and farmer learning approaches based on constructivism view to assess agricultural sustainability. This sub-theme reinforces the above sub-themes by integrating farmer learning techniques, combining indigenous technical knowledge and science to bring various dimensions of sustainability to bear. Knowledge and perceptions on agricultural sustainability (publications 13-15) brings out farmers, scientists and extension workers views thus strengthens the previous sub-themes through qualitative and quantitative assessments.

2.3.3 Limitations of the Body of Works and Future Perspectives

The submitted body of works are situation specific and needs to be corroborated in other similar environments. For example, the indicators and thresholds and the results can only be generalised to similar environments. However, governmental policy, regional and national unstable environments, culture and belief and availability of knowledge may limit the extent to which these results can be extrapolated and applied to other locales. The body of works does not cover all possible combinations of factors that may influence ecological and socio-economic sustainability, but restricts itself to those that can either be easily measured or those that are perceived to play an important role. This work attempted to overcome this shortcoming by using two models: (NUTMON[10]) and (QUEFTS[11]). These models are innovative and are considered "being a first"[12] since they had not been used widely in Kenya. While the data generated by these models were important in assessing agricultural sustainability, the models in themselves are static and cannot be used to study temporal dimensions of sustainability (long-term dimensions). In future, there is therefore a need to link the outputs of these models with simulation models for assessing the direction of change in agricultural sustainability over time. Furthermore, evaluation of interventions for addressing agricultural sustainability requires a dynamic model to extrapolate effects in time and to determine the effects of potential interventions on agricultural sustainability through feedback mechanisms. Currently there are limited simulation biophysical models that can, for example, simulate nutrient balances over time. The available static and biophysical models are usually propriety softwares with costs beyond the reach of many researchers.

The temporal dimensions of sustainability need further attention in the future. There is need to use long-term time-series data to reliably build an authentic picture of agricultural sustainability of smallholder farms. The study was limited by availability of time-series data.

The body of works has not integrated some aspects of soil quality in comparative assessment of sustainability of LEIA and organic farms against conventional equivalents. For example soil quality assessments in terms of microbial soil biomass and activities are increasingly becoming important in sustainability assessments yet are not included in comparing organic and conventional farming systems in the submitted body of works. This was due to constraints during research regarding costs

[10] NUTMON: Monitoring nutrient flows and economic performance in tropical farming systems; (NUTMON pilot phase activities started in Kenya in 1994; Prior work in 1993 by Smaling (1993)

[11] QUEFTS: Quantitative Evaluation of Fertility of Tropical Soils

[12] PLAR: The roots of PLAR (participatory Action Research) begun to emerge in 1994 in Southern Mali in the form of Participatory Action Research (See Section III), with the concept further developed in Western Kenya as PLAR in late 1990s through KARI/KIT collaboration

of collecting such data and the lack of infrastructure required for such analysis at the time. Furthermore microbial biomass assessment was not a widely used method in assessing farming systems in Kenya at the time of the study. Future studies are needed that can address this gap. Similarly, biodiversity and other indicators, which are relevant for getting a reflection on land use and on-farm organic matter production and carbon sequestration, are not addressed by the body of works as were productivity factors such as pests and diseases. There was inadequate data on short and long-term data on pests and predator dynamics during the time of the study.

Research in Kenya is challenging to conduct. It is not free and so funding needs to be sourced. For these reasons issues that I would have wished to include were not possible including issues on energy consumption and emission of greenhouse gases, detailed input-output markets, transportation and infrastructure and credit that influences produce prices, and therefore farm sustainability. I did not include these aspects due to methodological challenges and the associated costs. In the future, studies are required that can integrate these issues in smallholder farming system studies in sub-Saharan Africa

Furthermore my public works have not given focus to the interactions between national and global policies, and farm-level sustainability but concentrated on assessing sustainability at “local study sites”. However, from my public works it has become apparent that future studies may need to give emphasis to the impacts of these policies on farm-level agricultural sustainability.

CHAPTER 3: POLITICAL AND SOCIO-ECONOMIC ENVIRONMENT AND HOW IT INFLUENCED MY RESEARCH

In this section, I describe the political environment and changing agricultural policies in Kenya and how they impacted on my research with regards to choice of study sites, use of agricultural inputs, choice of research approaches, dissemination of research findings and farmer adoption of agricultural practices. The description focuses on the period 1993-to-date, but also draws parallels to the impacts of policies implemented under different regime changes before 1993 that had an impact on the period being covered by my works.

3.1. Changing policies and the selection of study sites

The combined effect of national policies, agricultural production patterns and biophysical and human settlement patterns in Kenya led me to select study sites in both high and low-to-medium agricultural potential areas to capture diversity of farmers' socio-economic circumstances and the disparate biophysical environment in which agriculture is practiced. The pre-and-the immediate post-independence period (post 1963) policies such as *Sessional paper No. 10 of 1965 on African Socialism and its Application to Planning in Kenya* and *Sessional paper No. 1 of 1986 on Renewed Growth for Economic Development* partly contributed to creating socio-economic disparities between the high and low-to-medium agricultural potential areas by concentrating resources and research efforts in the high agricultural potential areas. Thus, I conducted research in both high and low-to-medium agricultural potential areas to capture this diversity in smallholders' circumstances.

The biophysical restriction of agricultural production and human settlement to 16-17% of Kenya's total land mass, the rising population pressure in high agricultural potential areas with some administrative districts registering 300-758 persons km^2 (KNBS, 2011) and population migration from high to low-to-medium agricultural potential areas further informed my perspectives on conducting research that covers all these areas (Map Figure 2: Map of Study Areas

Furthermore the fact that agricultural production in Kenya is dominated by smallholders accounting for 75% of total agricultural output and up to 70% of total marketable agricultural commodities (ASCU[13] 2012) and that they have been historically marginalised in terms of their full participation in research influenced my thinking in targeting them for this research.

However, the inclusion of both high and low-to-medium agricultural potential areas in the study appeared to have added additional logistical requirements due to distances needed to be covered; number of research sites managed and depth of data collection required. However, it turned out to be useful in assessing agricultural sustainability due to contrasting biophysical characteristics, farmer social and cultural circumstances and differences in farming skills and adoption of technologies appropriate to specific agro-ecological zones and culture. These differences enriched the studies undertaken and provided a wide scope for interpretation of the findings in terms of capturing facilitating and limiting conditions that influence agricultural sustainability in specific agroecological regions.

[13] ASCU: Agricultural Sector Coordinating Unit

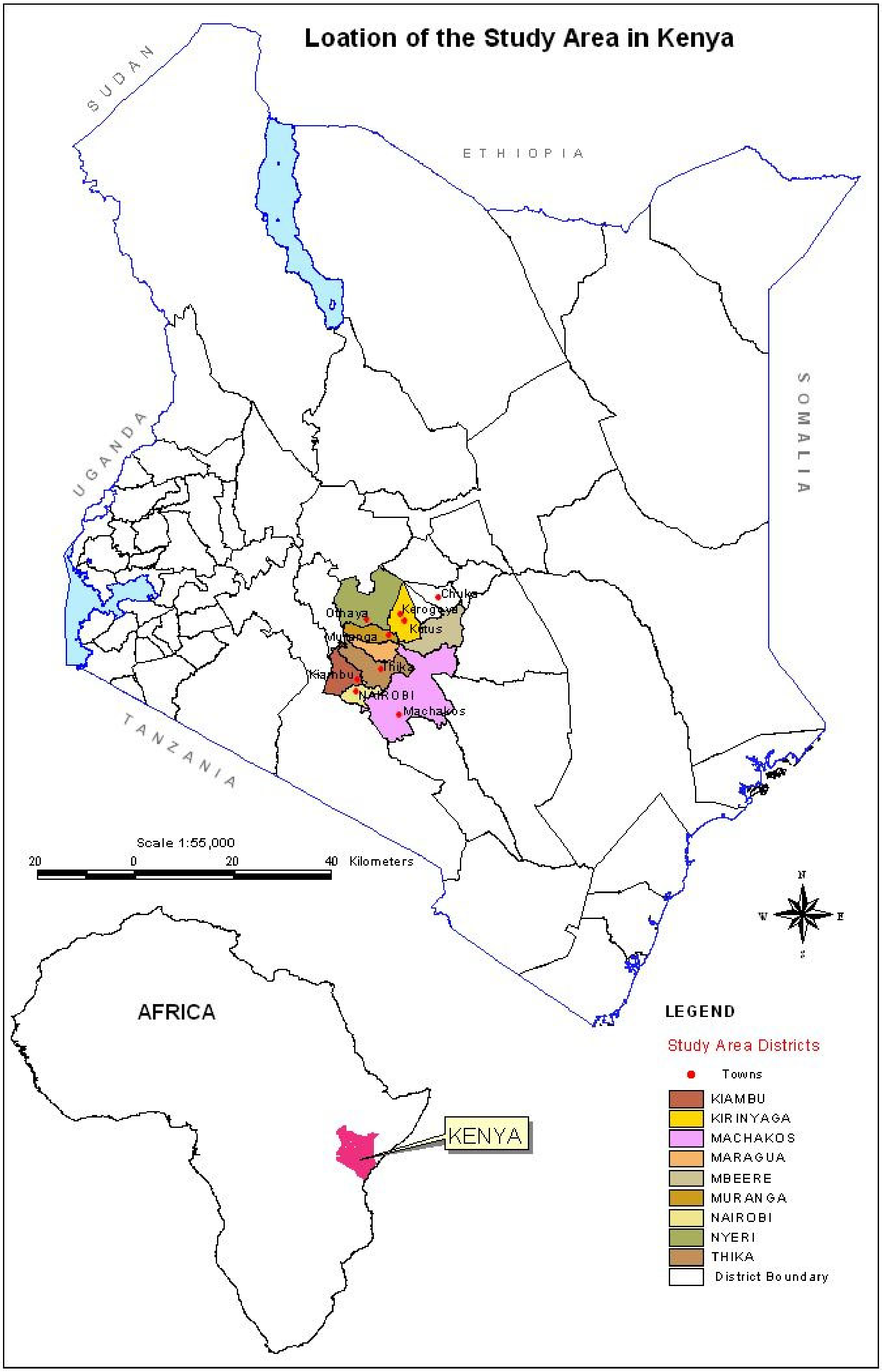


Figure 2: Map of Study Areas

As a result of conducting this research this way, I have learnt that smallholder farmers are rational in their decisions, especially in applying local knowledge of their environment to cope with challenges in the biophysical environment. Most farmers have evolved farming methods based on indigenous technological knowledge through observation, trial and error partly making them “good traditional scientists”. This local knowledge was an important input into the research process with farmers in the high agricultural potential areas tending to propose technologies which require relatively more capital outlay for participatory experimentation than their counterparts in the low-to-medium agricultural potential areas, probably due to differences in resource endowments and willingness to take relatively high risks.

3.2. Agricultural sector and extension policy environment and impact on my studies

This study was undertaken in the period when agricultural productivity in Kenya was low, reflected in low yields per acre of land, dwindling smallholder income and a low capacity of smallholders to purchase agricultural inputs. The Kenyan Government initiated policy reforms, 1991-94, to increase private sector involvement in fertiliser industries and availability by decontrolling fertiliser prices, abolishing licensing requirements for imports, freeing foreign exchange regimes and removing value-added tax on fertilisers. Although these reforms resulted in increased availability of fertilisers, it resulted in problems of quality and affordability and disparity in use of fertilisers with most fertilisers used on large plantations, on major cash crops while smallholder subsistence farmers use low-to-nil quantities of fertilisers.

The above gave birth to the idea of investigating the potentials and limitations of LEIA and conventional farming systems. This covers works 6, 7 and 8. LEIA such as organic farming has been promoted in Kenya since late 1980s/early 1990s as alternative farming systems at low cost with a potential to manage agricultural resources including environmental conservation while meeting changing human needs. However, their sustainability has been a subject of debate (De Jager *et al*., 2001). LEIA had never been systematically examined in Kenya, prior to this study, despite being promoted by non-public extension organisations during this period.

The policy environment and limited access to external inputs that require cash outlay, my research leaned towards integrated input use combining organic and inorganic sources of fertility (publications 9, 10 and 11). This was based on farmers' proposals during joint experimentation design in which it was clear that the use of locally available low cost inputs suits farmers' socio-economic circumstances. With hindsight, this turned out to be a wise move. In the low agricultural potential areas, the use of manures and other organic farming practices brought dramatic results as a result of improvement in soil physical and biological properties with yields out competing those of conventional farmers' normal practice of using limited inorganic fertilisers. However, other authors have noted that no evidence exists to link the use of such technologies to resource poor farmers only (Tripp, 2006). They can be practised by all types of farmers.

Part of these studies (publications 6, 7 and 8) were conducted in 1994-1999 when public extension in Kenya comprised Extension and Visit methodology (1982-1998) funded by the World Bank (World-Bank, 1999); the Kenyan Government was the sole extension service provider; the adverse effects of structural adjustment programmes on agricultural sector were still being felt and there was dismal performance of the extension services: poor research-extension linkages; neglect of women farmers; focus on large land owners instead of smallholders, and particular attention given to more educated and better-off areas. As such, the performance of the public agricultural extension service in Kenya was questioned and its effectiveness became a controversial subject (IFPRI[14], 2009). I exploited these "emerging opportunities" in the sytem to undertake studies leading to publications 6, 7 and 8 using "farmer research and extension groups" in low-to medium and high agricultural potential areas of Kenya, actively involving farmers in research contrary to mainstream research studies at the time. Thus, these studies were among some of the pioneers using the FREG[15] methodology in Kenya.

[14] IFPRI: International Food Policy Research Institute
[15] FREG: Farmer Research and Extension Group

I produced Works 9, 10 and 11 using FFS methodology in the period 2001-2008. FFS is a facilitated learning process based on group extension and research methodology and adult learning principles thereby stimulating local innovations for sustainable agriculture. My use of FFS was made easier in this period as the Government of Kenya was continually re-structuring legal and policy frameworks to improve research and extension environments and to allow for participation of other stakeholders through various frameworks: National Agricultural Extension Policy (NAEP) in 2001, Strategy for Revitalising Agriculture 2004-2014 (GoK, 2004), Agricultural Sector Development Strategy (2010-2020) and National Agricultural Sector Extension Policy (NASEP) in June 2012 (GoK, 2012).

The various policy frameworks above provided an enabling environment for inclusion of FFS in public extension and national agricultural research systems. Thus, the use of FFS either as an extension methodology or as an extension-research methodology has gained currency in Kenya. I used FFS in this period because the methodology empowers farmers to implement their own decisions in their own fields based on an informed understanding of the agro-ecosystem thus developing their capability to be better managers of their farming systems. Furthermore, FFS seeks to assist farmers develop critical and informed decisions that render production systems more productive, profitable and sustainable in the face of changing environmental, technical and economic conditions (Onduru *et al*., 2002). However, at the time of these studies, FFS approach was majorly used to enhance farmer learning and experimentation in annual crops and its application to perennial crops, soil fertility management and promotion of sustainable agricultural practices was limited. Publication 11 is a pioneer work in Kenya in terms of applying and adapting FFS to smallholder tea production with the goal of making smallholder tea production sustainable.

3.3. Agricultural research policies in Kenya and its impacts on the studies conducted

Although agricultural research was initiated in the 19th Century prior to Independence, a national research policy was not formulated by the post- independence Governments until June 2012 despite various pieces of legislation that touch on research issues such as the Science and Technology Act CAP 250 of 1979 (Laws of Kenya) that established various public research institutions. Since independence, research was considered a public sector activity despite numerous other players namely civil society organisations, producers, private sector and public universities among others. These players were initially ignored but are now recognised as research players under The National Agricultural Research System Policy (NARS) framework formulated in June 2012. However, I note that the absence of National Agricultural System Policy in Kenya when these studies were conducted did not affect how I implemented these studies and shared results. Many fora already existed to share the research results. Similarly, strategic partnership in research between different research bodies including public research institutions with civil society, private sector players and NGOs already existed even without the regulatory policy framework. The majority of publications included in this context statement draw their strength from strategic partnership forged with national public research institutions and universities, both in Kenya and other countries (publications numbers 1 to 5, 8 to 14); and appear to be forerunners of the spirit contained in NARS before it was formulated. For example, NARS recognises the necessity to harness the best science, technology and indigenous knowledge in implementing research agenda, an objective that cuts across all the studies presented here.

CHAPTER 4: EPISTEMOLOGICAL POSITION AND A CRITIQUE OF METHODOLOGY AND METHODS

4.1 Background

I started reflecting on issues of epistemology when writing this statement since my formal education put more emphasis on "research methods" than the process of conducting research which includes understanding research paradigms and philosophies that underpin research, generation of knowledge and how knowledge can be justified. In my review of literature, in the last six months, I felt that the more I read about paradigms and philosophies of research, the more I got confused by the divergent opinions of various authors until I came to the realisation that epistemological position is my personal way of how I see the world and what constitutes reality thereof, how I believe knowledge can be created and communicated, how I define truth and how I relate with the people I am collecting data from in the process of ascertaining whether something is real or true, and how these views have influenced my thinking in conducting research and in interpreting research outputs. The more I reviewed and reflected on my research journey over the last 20 years, the more I realised that the research approaches and methods I have employed derive their roots from the pragmatism paradigm underpinning a mixed-methods research approach.

Pragmatism is a philosophical partner for mixed methods research and can be traced to the work of Peirce, Dewey, Mead, William James, Blumer and Goffman (Burke Johnson & Onwuegbuzie, 2004; Denscombe, 2008). It offers an alternative paradigm to underpin mixed-methods research and *partly evades* the positivist and constructivist paradigm wars of 1970s and 1980s characterised by incompatibility thesis and the purists' "methodological acrobatics" (Sandelowski, 2001). It recognises that research paradigms can remain separate, but can also be mixed into another paradigm in peaceful co-existence and that the incompatibility thesis of the paradigms is invalid (Burke Johnson *et al.*, 2007). It suggests how research approaches can be mixed optimally to answer research questions of interest. The paradigm rejects traditional dualism including: epistemological (objectivism vs subjectivism), ontological (single reality vs multiple reality), axiological (value-free vs value-bound), methodological (deductive vs inductive and abductive logic) and rhetorical (formal vs informal writing style) beliefs for a moderate philosophical dualism based on how well the philosophical stances work in solving problems (Burke Johnson & Onwuegbuzie, 2004).

Pragmatism has an inclusive ontological realism where everything deemed to be real is taken into account: subjective realism, inter-subjective realism and objective realism (Onwuegbuzie & Burke Johnson, 2006). It recognises internal and external reality and their interactions, multiple affordances and levels of analysis and diverse disciplinary perspectives on what is being studied (ibid). Theorists have proposed three forms of pragmatism (i) pragmatism of the right-a moderately strong form of realism and a weak form of pluralism (Putnam, 2002); (ii) Pragmatism of the left-antirealism and a strong pluralism (Brandom, 2000; Maxcy, 2003); and (iii) pragmatism of the middle-taking an in-between position (Burke Johnson *et al*., 2007), with the latter (iii) resonating with what I do and what I have been doing.

Pragmatism's epistemological position is that of inter-subjective approach to knowledge generation and justifies knowledge through epistemic values and standards. Knowledge is constructed based on the reality of the world we experience and live in. According to Creswell (2003) pragmatism provides a basis for knowledge claims based on the following (i) accepts multiple beliefs on reality. Paradigms can be mixed to enable researchers to combine qualitative and quantitative research approaches; (ii) rejects dualism between the mind and reality that is external to the mind and *accepts that truth is what works*. Researchers are therefore able to choose both qualitative and quantitative methods for optimal understanding of the research problem and to use qualitative, and descriptive inferential analysis; (iii) research questions to be answered determines the choice of methods, techniques and procedures to be adopted in research; and (iv) emphasises functional knowledge by framing research impacts and research process on what is envisaged to be achieved and its consequences; and thus researchers need to provide a rationale for combining quantitative and qualitative data. The paradigm observes knowledge justification criteria associated with positivism (reliability, internal validity, external validity, objectivity) and constructivism (trustworthiness, dependability, confirmability, transferability and authenticity).

This paradigm, rejects reductionism whilst viewing human inquiry as trying different things to see what works as analogous to scientific inquiry that provides warranted evidence ultimately leading to higher truths (practical epistemology) (Burke Johnson & Onwuegbuzie, 2004). It endorses fallibilism, views current beliefs and research conclusions as rarely perfect, certain or absolute; and pluralism (eclecticism)[16] e.g. methodological pluralism and pluralism of theories and perspectives with observation, experience and experiments all being understood as useful in gaining understanding of people and the world.

In terms of values (axiology), it recognises a value-oriented approach to research based on cultural settings and endorses shared values such as democracy, freedom, equality, empowerment, liberation and progress. It posits that research is value laden and there are internal and external values that need to be considered. A researcher therefore needs to take into account personal values when conducting research including interpretation of data and making recommendations and in judging one's own study. In terms of how we can write about knowledge (rhetoric), pragmatism proposes the use of formal and informal writing styles, using both impersonal and personal voices as appropriate.

4.2. Ontological and epistemological positioning of my Public Works

Pragmatism, underpins my view on agricultural sustainability and has offered me a congruent articulation of the influences at work on my thinking on research design, conduct of research, and the production of my public works.

My world view, ontology and epistemology

When I started to conduct my research work on organic farming and agricultural sustainability in 1993 and the subsequent research work on integrated nutrient management for sustainability of smallholder farms, unknowingly, my world view on agricultural sustainability and its definition influenced my thinking on the research process. Indeed, a challenge in the infancy stages of my research in 1993 was how to

[16] Eclecticism is a concept that recognises multiple paradigms, assumptions, theories, styles and ideas to gain insight into a subject

conceptualise organic farming and agricultural sustainability so as to formulate appropriate research designs. It was then that I realised that multiple definitions of organic farming and agricultural sustainability exist in literature and their definitions and operationalisation remain contested. This contributed to my world view of sustainability which stands to be different from others in literature (UNCED, 1992; WSSD, 2002). My view of African smallholder farming systems is one where farm-components are inter-linked through nutrient and financial flows, ecological processes and markets mediated through policies and other factors in the socio-economic environment. Pragmatism has helped me now to better articulate and justify not only my world view on sustainability, but on potential pathways for sustainability and increased food production and specifically my eclecticism stance on research in my studies. I further view these farming systems to be "whole" functioning as one unit but with components which are interconnected and interdependent (holism). This holistic view of smallholder farming system informed my research to explore multiple dimensions of agricultural sustainability to create a *whole* understanding[17].

My view of smallholder farming systems as complex entities with interdependencies among its components informed my thinking in adopting holocentric view of agricultural sustainability and food production which in turn informed my perspectives on conducting participatory learning and action research, interdisciplinary research, and multi-site studies taking into account farmers bio-physical environment and socio-economic circumstances. The pragmatism paradigm informed my research process in understanding farm-level complexity and agricultural sustainability, in formulating research designs that are situation and context appropriate and in striving to raise farmers' voice to enhance agricultural sustainability. More so when conducting research, I persistently asked myself the question, *whose reality do I need to take into account when conducting participatory and interdisciplinary research in a contested theme, agricultural sustainability*? I soon realised that my answers were similar to Ducasse's nine decades ago when he said:

[17] Some authors have advanced the view that there is "no philosophical, ideological or practical contradictions between reductionism and holism in scientific synthesis" and there is need to use both in a study (Østreng, n.d.). Reductionism suggests that in order to reach a scientific understanding of the nature of a complex phenomenon, it must be explained by using only a single factor as the cause (Bethanymlynch, 2012)

"*No ontological position can be either proved or refuted; and therefore that any ontological position which is meaningful is tenable, and that its adoption or rejection is thus in the end purely a matter of one's personal taste at any given time*" (Ducasse, 1924).

The research approaches I adopted required a process of negotiation bringing various stakeholders' world views together and notions of reality into nearly "a unity in diversity situation" with ceded grounds and areas of consensus. This had implications on how I conducted my research. I integrated my perspective, realities of my collaborators and farmers' understanding of reality into the research design process and I agreed with Eisner (1990) when she said that "*truth is ultimately a kind of mirage that in principle cannot be achieved because the worlds we know are those crafted by us*". I further concur with Lafaille & Wildeboer, (1995) when they noted that different interpretations of reality can co-exist, in space and in time, for science is a pluralistic phenomenon. I am a proponent of inclusive ontology as advocated under pragmatism. I have recognised in my public works that objective realities do exist but also multiple realities, that research paradigms can be combined and peacefully coexist and that quantitative and qualitative research approaches can be logically combined, as are data analysis methods, to enhance our understanding of a complex world. This pluralistic thinking and eclecticism guided my works, for example the research process I used between 1997 and 1999 (INMASP Project) was informed by inclusive ontology: ontological realism (publications 1, 2, 3 and 4) and a mix of ontological realism and relativism (publications 9, 10, 13 and 15). This commitment to ontological inclusiveness has informed all my public works.

Historically, privileging a particular ontological position demanded a commitment to a particular epistemological position and methodological assumptions, though recently there is a growing understanding in adopting flexibility in interpretation (Miller & Fredericks, 2002). My works, I have come to realise were informed by what is termed epistemological pluralism but I had developed this position from years of assessing practices through the multiple lenses of context, limitations, availability, accessibility, much needed action, funding and personal and professional motivations among other things. This stance enabled me to examine the sustainability of smallholder systems and to provide insights that cannot be gained by focusing on social, economic and ecological dimensions separately and more so when society's values and goals view the concept of sustainability differently. Epistemological pluralism informed my thinking in adopting an interdisciplinary research approach. Interdisciplinary research has an applied orientation and a high degree of integration: unity in formulation of research problems, sharing of methods and data interpretation among others. Thus I posit that there are many ways of knowing and any single way of knowing is insufficient for understanding the complexity of agricultural sustainability i.e. knowledge is both constructed and also based on reality of the world that we experience.

Epistemological pluralism informed the methodologies and methods I used in my research practice which are situated within a mixed-methods research approach. Mixed methods research has been defined as:

"*… research designs with philosophical assumptions as well as methods of inquiry. As a methodology, it involves philosophical assumptions that guide the direction of the collection and analysis of data and the mixture of qualitative and quantitative approaches in many phases in the research process. As a method, it focuses on collecting, analyzing, and mixing both quantitative and qualitative data in a single study or series of studies*" (Creswell & Plano Clark, 2007: 5).

The principle assumption here is that elements of research categorised under quantitative and qualitative approaches (with distinct linkages between methodology, methods and data types) can be combined in a research design. Quantitative and qualitative approaches are traditionally perceived to be underpinned by objectivism and subjectivism epistemologies respectively while epistemic values and standards under pragmatism underpins their combined use. To position my research design in relation to my epistemology, I have used an 8-category of mixed methods research design proposed by Leech & Onwuegbuzie (2009) and tempered this where relevant with the classfication categories of Creswell *et al*. (2003). My various research designs provided a structure and a framework for my data collection and analysis and linkages to all elements of my research put together.

I used fully mixed concurrent design (FMC) in 1994-1996 in OFEA project (see publications 6 and 7 in Chapter 1) fitting within classification given by Leech & Onwuegbuzie (2009) and within my broader framework, comparative on-farm participatory research methodology. I used participatory research design to give farmers a voice in the research process and in technology generation, a design that falls within Creswell *et al*. (2003) classification of concurrent transformative design. The fully mixed concurrent design mixes qualitative and quantitative approaches *"within one or more or across the following in a single research study: the research objective, type of data and operations, type of analysis and type of inference"* (Leech & Onwuegbuzie, 2009). My purpose of mixing the two approaches was to corroborate quantitative and qualitative data, obtain an indepth understanding of practices from different angles as practiced by farmers and to get a complete picture of the performance of farming techniques as perceived by farmers themselves. Mixing of approaches took place when I was formulating research objectives, during data collection using semi-structured questionnaire, during farmer-researcher group meetings and during analysis and presentation in which I analysed quantitative and qualitative data alongside each other. I used descriptive statistics to analyse quantitative data while I summarised qualitative farmers opinions into thematic categories, as direct quotes on their own and or used them to corroborate quantitiative findings. I implemented this design in multi-sites to enhance validity and generalisation of findings.

In the period 1997-1999, I used fully mixed concurrent dominant status design (FMDS) under LEINUTS Project (publicationsin 8, 12 and 14, Chapter 1). This design is the same as FMC except that the quantitative approach was given more weight in terms of time allocation for data collection and analysis (Leech & Onwuegbuzie, 2009). Using quantitative approaches comprised studying nutrient flows and balances and farm financial performance using nutrient monitoring methodology (NUTMON, see Section 3.2.3) while in the qualitative approach I used participative tools (e.g. resource flow mapping), researcher-farmer group meetings, field days and development scenario workshop meetings. I further used a mix of quantitative and qualitative aproaches in the participatory technology development component of the study. The rationale of mixing the approaches was expansion i.e. to enlarge the breadth and depth of the study by using different methods and interpretations, enhancing farmers' participation in the research process, corroborating the results of NUTMON studies and widening the scope of interpretation of the results. Data analysis comprised descriptive statistical analysis (e.g. NUTMON quantitative data, PTD data etc.) and qualitative data analysis from the outputs of participatory tools. Convergence of quantitative and qualitative data also occurred during data interpretation and farmers feedback workshops in which I used quantitative and qualitative visual tools to present and discuss results.

I further used fully mixed concurrent dominant status design under INMASP Project (publications 1, 2, 3, 4, 9, 10, 13 and 15, Chapter 1) in the period 2001-2005; and in Sustainable Tea Project (publication 11) in participatory research and learning processes. This design is similar to the one used above in the period 1997-1999, however learning in FFS[18], a predominantly qualitative approach was given more weight in terms of time duration than the quantitative-qualitative diagnostic part of the study. This design also had a perspective of partcipatory learning and action research, smallholder farmer empowerment and collective action and learning for sustainability. This therefore fits in Creswell *et al*. (2003) classification of concurrent transformative design. The purpose of integrating the quantitative and qualitative approaches was to widen the breadth of the study and to complement and strengthen the FFS learning process. In the quantitative diagnostic phase I collected data using NUTMON/Monitoring for Quality Improvement (MonQI) methodology (see section 3.2.3) to quantify nutrient flows and balances, assess soil fertility status and farm performance and constraints. I collected qualitative diagnostic data concurrently using participative tools to identify soil fertility management contraints and opportunities as well as the constraints facing smallholder annual crop and tea farmers. These tools included brainstorming and group discussions guided by a checklist, matrix scoring and ranking and other PRA tools. The diagnostic phase was part and parcel of FFS where I facilitated learning on integrated nutrient management and on sustainable tea management using adult learning philosophy, learning-by-doing throuh participatory technology development and agro-ecosystem analysis and sharing of experiences. This provided opportunity for farmers to construct meaning based on their experiences and the facilitated learnining process (constructivism epistemology). Mixing approaches took place at the formulation of project objectives, during data collection (e.g. use of questionnaire collecting quantitative and qualitative data), agro-ecosytem analysis and during FFS meetings in which qualitative and

[18] Farmer Field School

quantitative results were discussed. Data anaysis also included descriptive statistics (with summaries presented in visual forms), cross-over analysis in which descriptive statistics were used to analyse semi-quantitative matrix scoring and rankig data, and summaries of qualitative data analyses.

Just like most of my publications, I used fully mixed concurrent dominant status design under Green Water Credits Project to produce publication No.12. Although quantitative and qualitative approaches were used concurrently, quantitative appoach was dominant in terms of the time dedicated for data collection and analysis. I used semi-structured questionnaires to collect data, collecting both quantitative and qualitative data concurrently. Furthermore, I collected qualitative perceptions from local experts and key community experts (community markers) to ascertain and triangulate information collected at farm level. In addition I collected secondary data (quantitative) for corroborating primary data during data analysis and interpretation. There was also the convergence of the two approaches during data analysis and interpretation with qualitative data used to interpret quantitative data. Data analysis comprised descriptive statistical data analysis and qualitative analysis with the latter used to interpret the former.

Axiology and Rhetoric

Axiology is the science of human values and enables us to identify our values, attitudes and biases that influence our perceptions, decisions and actions we take and what we consider to be ethical and moral in research (Hesse-Biber, 2010; Mertens, 2007). Anchored in my approach my works were informed by the belief that research processes are value-laden, that I need to take personal values and attitudes into account and that research needs to be contextualised in the culture in which it has been conducted. My values that knowledge generated through a research process can be technical but also qualitative, my emancipatory interest in farmers welfare (the need to raise farmers voice through empowerment and collective action), practical interest to co-generate knowledge together with smallholders and my bias on sustainability of smallholder agriculture prompted me to adopt participatory, interdisciplinary and emancipatory approaches (e.g. publications 6, 7, 9, 10, 11 and 12). In these processes, I valued the power of using a combination of quantitative and qualitative data to understand reality with quantitative data being translated into "easy to understand language" (e.g. see publication No. 14), negotiating agreements during the research process and building trust; recognising farmers full participation in the research process and recognising their voice and opinions; promoting social good and minimising harm and risk, for example through participatory PTD design that includes farmers practice as control rather than zero-control; conducting inclusive research that draws both men and women participants; extending local success to wider community; and maintaining confidentiality of farmers, for example through presenting aggregate data on farmer incomes for discussion.

My axiological assumptions above and my belief in epistemological pluralism, informed my rhetoric assumptions and thus the language I used in the research process and in reporting the research results. Rhetoric is the art or science of language and oral and written communication (Johnson & Christensen, 2012). Philosophical traditions have dictated the language that can be used to report research results, for example the use of formal writing style (impersonal voice) for positivist researchers and the use of informal writing style (personal voice) for constructivist researchers. My writing style in the public works has been dictated by the type of audience targetted by the various publications. At farm level the language used was based on visual aids and or easy to understand presentations while for the extension and research community the language and style was that of peer reviewed scholarly journals.

4.3. Methodology and Methods

Methodology is "a strategy or plan of action that links methods to outcomes and governs our choice and use of methods" (Creswell, 2009). It justifies the use of specific methods and choices made. My epistemological pluralism informed my methodologies to collect both quantitative and qualitative data (mixed methods approach)[19] and the path I eventually adopted in analysing data and interpreting the same to create knowledge. On the other hand, methods are techniques or tools for gathering data and analysing it and can be considered as practical activities of research, for example activities, techniques or tools related to sampling, data collection, data management,

[19] Research approaches include quantitative approach (underpinned by the positivist/postpositivist paradigm); qualitative approach (informed by constructivism paradigm) and mixed methods approach (pragmatism paradigm).

data analysis and reporting (Carter & Little, 2007). In the subsequent paragraphs, I have explored in detail the major methodologies I used and given a summary of methods in Appendix 3.

I have used diverse methodologies in my public works, variously described under the following umbrella categories: (i) participatory learning and interdisciplinary research; and (ii) Decision support system and models. The former include on-farm participatory comparative research, participatory technology deveopment (PTD), Participatory soil mapping and characterisation, and Farmer Field Schools (FFS) while the latter includes NUTMON, MonQI and QUEFTS methodologies. I present these methodologies in turn in in the subsequent paragraphs.

4.3.1. On-farm participatory comparative research

I used this research methodology in 1994-1996 to study the potentials and limitations of organic farming techniques in medium and high agricultural potential areas of Kenya. In adopting this design I was faced with several initial choices (i) should I study organic farming by itself or compare it with conventional system?; (ii) should I conduct research on-station or on-farm?; (iii) should the whole organic farming system be studied or selected techniques? Discussions on these methodological choices are presented in Publication No. 6. I adopted on-farm comparative research, studying organic farming techniques with their conventional equivalents to capture actual farmers experiences, performance of organic farming as implemented by smallholders, allow for farmers full participation in the research process and to integrate smallholders technical indigenous knowledge in the research process. At the time of the study, most farms were still under transition to organic farming and thus whole farms could not be considered “organic”. The research concentrated on most frequently practiced organic farming techniques, namely compost and liquid manure, double digging and botanical pesticides and their conventional equivalents. This methodology proved useful in studying organic farming as is actually practiced by farmers which in some cases differed from recommendations. It also proved useful in building trust with farmers, in enhancing validity and generalisation of results due to use of multi research locations and in allowing farmers to be fully involved in the research process. I further found the use of this methodology important in co-generation of knowledge with farmers and in prompting farmers to act and implement practices which had attracted them during the research process.

A challenge with this methodology is the selection of sites in the farmers "field". My experience shows that site selection, experimental design and provision of research inputs should be a process of negotiations. Some of the farmers participating initially allocated the most poor sites of their fields for research. Similarly, there were some inputs (e.g. spring balances for measurements) which were not easily available at farm level and required intervention of researchers. Another challenge with this methodology was attitude and commitment. This methodology required a change in my attitude as a researcher in working with farmers, paying attention to systematic trial design, recognising farmers contributions and creating a mutual understanding of each others needs to enhance impacts.

By adopting this methodology, I further came to learn that research based on comparative farming system approach to generate data that can influence practice and policy required as much labour and time in studying organic farming system as their conventional equivalent. Thus it requires nearly twice as much resource as an assessment of organic farming on its own, in comparison with regional averages or a hypothetical model, or a controlled experimental approach.

4.3.2. Participatory technology development (PTD)

I embedded Participatory technology development (PTD) in my research projects (e.g. publications 9, 10, 11 and 12). With reference to agriculture and natural resource management PTD is a collaborative effort among research, extension, development agencies, service provides and land users to develop and spread improved farming and land husbandry practices (Veldhuizen *et al.*, 2003). Through the PTD process, I experimented together with farmers on integrated nutrient management technologies and on sustainable agriculture practices in tea.

My choice to include PTD in my research work was guided by its transformative-emancipatory paradigm: giving a voice for smallholder farmers to fully participate, define reseach goals and choose methods; its recognition of indigenous technical knowledge; and its focus on co-generation of knowledge and enabling farmers to act and change their situation. I was also attracted to it because it provides a learning and experimentation platform enabling farmers to improve on their observation and experimentation skills. My positive experiences with PTD include the fact that it facilitates the process of farmers taking action to implement appropriate technologies that suit their circumstances, see publication No. 10 and co-authored on line available publications, Onduru *et al*. (1999), De Jager e*t al*. (2001) and De Jager *et al*. (2004). It also facilitates partnership building and knowledge and resource sharing. However, I experienced some challenges. When I started using PTD in the first half of 1990s, what I thought would be a straightforward approach with a potential to have demonstrable results in a short time period turned out to be a "longer duration process of engagement". I attribute this to the long negotiations involved in use of participatory tools associated with PTD before building concesnsus and making decisions with farmers, the fact that my co-authors and I introduced flexibility into the PTD process as we learned by doing and avoided formal procedures of blueprints; and also the fact that we had to "de-learn" some of the attitudes and beliefs associated with our past training on conventional research methods. Another lesson we learnt is that PTD has a high demand for time-involvement in the field and for social skills (negotiations, dialogue and facilitation of partnership activities) and requires a different way of working, respecting farmers knowledge and experience and capacities. Other authors have also narrated unique experiences with PTD in other countries, some of which can be found in PTD/PID circula in Prolinnova website (PROLINNOVA, 2004).

4.3.3. Farmer Field Schools

Farmer Field School (FFS) was initially developed in 1989 in Central Java Indonesia through FAO-Assisted Integrated Pest Management (IPM) programme (see Chapter 2). I started using FFS in 1997 first to enhance smallholder farmer learning on integrated nutrient management and later, 2006-to-date, to enhance learning on good agricultural practices in smallholder tea, themes which had not been previously addressed using FFS. My rationale for using FFS was its central focus on learning, building farmers capacity and knowledge which in turn begates power, empowerment and building of local farmer institutions. Learning in FFS is facilitated and takes many forms: sharing of experiences and reflection, discussions, agro-ecosystem analysis, group experimentation, special topic sessions etc.

Learning in FFS is underpinned by epistemological pluralism: constructivits view that inform adult learning principles on which FFS is based, radical empiricism that affords equal status to multiple ways of knowing and underpins experiential learning, emancipatory-participatory epistemology that underly action learning and PTD trials in FFS and an evidential rationality epistemology that inform transforamtive learning on "how adults learn to think for themselves rather than act upon the assimilated beliefs, values feeling and judgements of others" (Rainey & Kolb, 1995; Mezirow, 2003; Duveskog, 2006).

My experiences with FFS in integrated nutrient management are consigned in publications Nos. 9 and 10 and on smallholder tea, publication No. 11 and other co-authored publications namely Tilburg *et al*. (2010) and De Jager *et al*. (2011). The methodology empowers farmers to gain knowledge, build confidence and improve on skills to implement agricultural practices based on sound knowledge and hands-on experience. As indicated in publications 9, 10 and 11 the potential benefits of FFS extend beyond learning on agricultural practices into building local farmer institutions and creating linkages with markets (see Chapter 2). Further experiences from using this methodology indicate that it needs to be embedded in wider livelihood activities inclusive of commercial activities, linkages to the market and improved farmer networking strategies to enhance farm sustainabilty. Furthermore, its wider applicability require making the process flexible and adaptable to new situations and cropping systems (publications 9, 10 and 11), building a pool of skilled facilitators who can carry the process forward, creating strategies for enhancing knowledge diffusion to non-FFS members and reaching out to vulnerable groups.

The critical premise of the two approaches (PTD and FFS) is emancipation and facilitating farmers to take action based on analysis of reality, sound knowledge and conscious awareness and co-ownership of all research processes and outputs(Charles and Ward, 2007). This is a concept they share with Participatory Learning and Action Research approach (Defoer *et al.*, 1998). Experiences in using PLAR in Western Kenya have been described in (Defoer, 2000).

4.3.4. NUTMON and MonQI

I used NUTMON methodology in publication number 3, 4, 8, 9 and 10 to bring the various dimensions of agricultural sustainability to bear-ecological (soils), economics and social factors. Monitoring nutrient flows and economic performance in tropical farming systems (NUTMON) is an integrated multi-disciplinary and multi-scale (plot, farm etc.) methodology (Vlaming *et al*., 2001a). NUTMON toolbox comprise a semi-structured questionnaire, a manual and a software for data entry and quantiative analysis of nutrient flows, nutrient balances and diverse farm financial performance indicators (cash flows, gross margins, farm income etc.). The toolbox is available online for free for universities, national research institutions and NGOs in developing countries (Vlaming *et al*., 2001b). The tool has been applied in China, Vietnam, Indonesia, Kenya, Uganda, Ethiopia, Burkina Faso and Ghana.

I used NUTMON in various ways, either as a main research methodology (see publications 8 and other co-authored publications-De Jager *et al*., 2001; De Jager *et al*., 2004)) or as a part of integrated methodologies which also focus on farmer learning (publications, 3, 4, 9,10 and Onduru *et al*., 2003). In the latter case, I used the outputs of NUTMON to inform the joint learning and participatory technology development (PTD) processes. Based on NUTMON methodology I jointly analysed together with farmers ecological and financial sustainability of smallholder farms and used the NUTMON quantitative indicators to inform farmer learning on various PTD activities.

My experience with NUTMON is that it provides, in a holistic manner, detailed information on nutrient flows, actual farm management practices, household and farm financial performance, farm productivity (crops, livestock etc.), and differentiates partial from full nutrient balances. In this way it provides a means for integrated assessment of sustainabiity as it capatures local farming reality in terms of biophysical and socio-economic environment within which farmers operates. However, the methodology has limitations: places high labour and time demand in data collection and analysis, has been prone to critisism on the use of some of the transfer functions to estimate hard-to-quantify nutrient flows, questioned on the data that relies on long recall periods, inadequecies in linking nutrient balances to soil nutrient stocks and its static nature and inability to capture dynamics of farm flows over time (details in

Chapter 8). Further discussions on challenges of using NUTMON can be found in Faerge & Magid, (2004) and in De Jager, (2007).

Partly due to the above challenges a succesor flexible tool, Monitoring for Quality Improvement (MonQI) is being developed (Envista Consultancy; Alterra-Wageningen University and Research, n.d.). MonQI is “a multi-scale and multi-disciplinary approach for monitoring management and performance of small scale agricultural enterprises world-wide with the aim of improving the quality of farm management, crop production, and quality of produce, livelihoods and environment” (ibid)). It has applications in joint learning (FFS, integrated nutrient management), environment (nutrients, pesticides and non-timber forest products), livelihoods monitoring (development of household assets and income) and monitoring agro-food chains for certification. I used MonQI to monitor the performance of smallholder tea systems in Kenya and as an input into joint learning, FFS (see publication No. 11 and Chapter 8).

4.3.5. QUEFTS

I used the Quantitative Evaluation of Fertility of Tropical Soils (QUEFTS) model to predict maize yields from soil chemical indices (Publication no. 2). QUEFTS predicts yields from soil nutrient supply and determines nutrient-limited yields assuming all other production factors are optimal (e.g. water supply) (Janssen *et al*., 1990; Smaling & Janssen, 1993). I used the model to calculate yield gaps ie. the difference between attainable yields and actual yields. The tool also allows for economic analysis of fertiliser use. The model was developed by Wageningen University and was first tested for maize in Surinam and Kenya. A challenge I experienced with the model is that it does not take into account other crop-growth and yield reducing factors such as soil moisture, weeds etc.

4.3.6. Inventory of expert knowledge and perceptions on sustainability

Qualitative approaches and perceptions of farmers form an “expert knowlede system” that can be used to judge the direction of agricultural sustainability (publication No. 13, 14 and 15). I inventoried farmers’ perceptions on agricultural sustainability, scientists perceptions on land degradation and farmer-researcher perceptions on soil fertility and soil quality indices to assess the direction of agricultural sustainability.

Farmer perceptions

I inventoried farmers perceptions on agricultural sustainability using a semi-stuctured questionnaire to capture perceptions on yield trends, soil fertility status, household and farm incomes, contribution of off-farm income to household income and household food availability over time. Analysis of these farmers perceptions proved useful in gauging the direction of agricultural sustainability of smallholder farms, especialy when corroborated with research-extension knowledge systems (publication No. 13). A lesson from this analysis is that farmers' perceptions is mostly qualitative, socially constructed, influenced by biophysical and management factors and may be "politically" mediateted.

Participatory soil characterisation

I undertook participatory soil charactersisation together with farmers (publication No. 14). This involved holding group meetings with farmers to identify farmers qualitative indicators of fertile and poor soils and general soil quality indicators followed by transect walks and participatory soil mapping in each individual farm. The mapping exercise in each farmer's individual farm identified different soil types, farmers perceptions of soil quality and fertility of each soil type, and constraints and potentials, and produced a soil map for each farm according to individual farmer's classification. The soil map was further analysed using pair-wise ranking and matrix scoring and ranking. Following this exerscise, I took a composite sample from each soil type mentioned by the farmer in each individual farm and conducted laboratory quantitative analysis for soil chemical indices and organic matter. The latter were compared with farmers qualitative indicators and perceptions using visual tools and later discussed in joint meetings.

This methodology allowed me to explore farmer-researcher congruency in knowledge bases, assess whether farmers qualitative indigenous technical knowledge which is rapid and less costly can be used for conducting rapid soil quality assessments and to built farmers confidence in their knowledge systems so as to individually respond to challenges of soil quality decline and therefore enhance agricultural sustainability. Challenges I experienced in applying this methodology included the high labour and time demand required to conduct the participatory exercises), translating the quantitative soil chemical indices into a language that farmers can understand (visual methods), and high costs of soil analyses which were dictated by the different soil types identified by farmers in each farm.

Perceptions on land degredation and case studies

I inventoried scientist's perceptions on land degradation from selected case studies analysing them against the robustness of indicators used and whether they truly indicate the extent of land degredation and its impacts at lower spatial scales (farm) (Publication No. 15). This inventory of perceptions proved a useful methodology in revealing the conflicting perspectives of researchers on extent of land degradation and its impacts in Africa's farming systems contending that there is need to move a way from empty rhetoric to capture reality on extent of degradation and avoid oversimplications and generalisations and alarmining statements.

4.3.7. Policy dialogue and development scenarios

Using results generated at farm level (nutrient balances and flows, PTD results and farm financial performance, farmer perceptions etc), district level data (trends in productivity, food security and other historical trends) and relevant policies we drafted qualitative development scenarios for discussions with district policy stakeholders in each research site. The workshop was attended by relevant Government Ministries (Agriculture; Environment and Natural Resources), Provincial Administration, private input suppliers, NGOs and other development agencies, research institutions, farmers and farmer representatives and the media. In these workshops we presented draft scenarios for soil fertility managent for the next coming 15 years to initiate policy debate. This was followed by a discussion and development of a desired situation for the next 15 years by the policy stakeholders including faciliating factors, constraining factors and actions to be taken by various parties to overcome constraints. However, these processes came too late, at the end of research process, (end of project) to allow sufficient time for follow-up on the action plans (publication No. 12). The lesson I learnt in this process is that policy makers need to be involved at an early stage in the research process. My co-authors and I have further described these experiences in a co-authored publication, De Jager *et al*. (2004).

CHAPTER 5: COLLABORATIVE INTERDISCIPLINARY RESEARCH PARTNERSHIPS AND LEADERSHIP

5.1. My Interdisciplinary Research Partnerships

I produced this body of works while engaged in collaborative and multi-institutional research partnerships undertaken in interdisciplinary teams (1993-2012). The partners were drawn from local and international development bodies and academic and research institutions (six African Countries and six European countries). My motivation to form research partnerships and an analysis of these partnerships using co-authorship network and metrics are presented in Appendix 4. In this Chapter, I describe my experiences and implications of conducting research in this set up and its implications. I used collaborative and interdisciplinary research because it demonstrates consensus on theoretical models and problem formulation and shared methodologies from different disciplines with coordination takes place at the level of collaboration and at the level of integration of disciplines and knowledge (Idil Gaziulusoy & Boyle, 2012).

5.2. Collaborating with Partners to Contribute to the Wider Knowledge Field

I have used my web of partnerships consummated through co-authorship network map as a proxy indicator of the complexities of interdisciplinary research partnerships and collaboration within which I produced this body of works (Figure 3; Appendix 4). In the subsequent sections of this Chapter, I present the attributes and benefits of this collaboration with partners to contribute to the wider knowledge field.

Benefits of collaboration

I realised 'added value' to my research through collaboration, which in my opinion would not have been possible had I undertaken the research alone or with the help of research assistants. The collaborative efforts enabled me to gain access to physical, financial and knowledge resources not easily available within a single organisation, within an individual researcher or available in a single discipline. It also built my capacity to influence the dissemination of research results to different target groups (farmers, researchers, development workers, policy makers etc.) and to nurture space for learning, innovation and networking on shared goals and research activities. Further this mode of research increased my visibility in the global research community through joint publications, removal of inequalities in the respect and regard accorded to young researchers and created space for understanding research processes and products and services at local and at regional level.

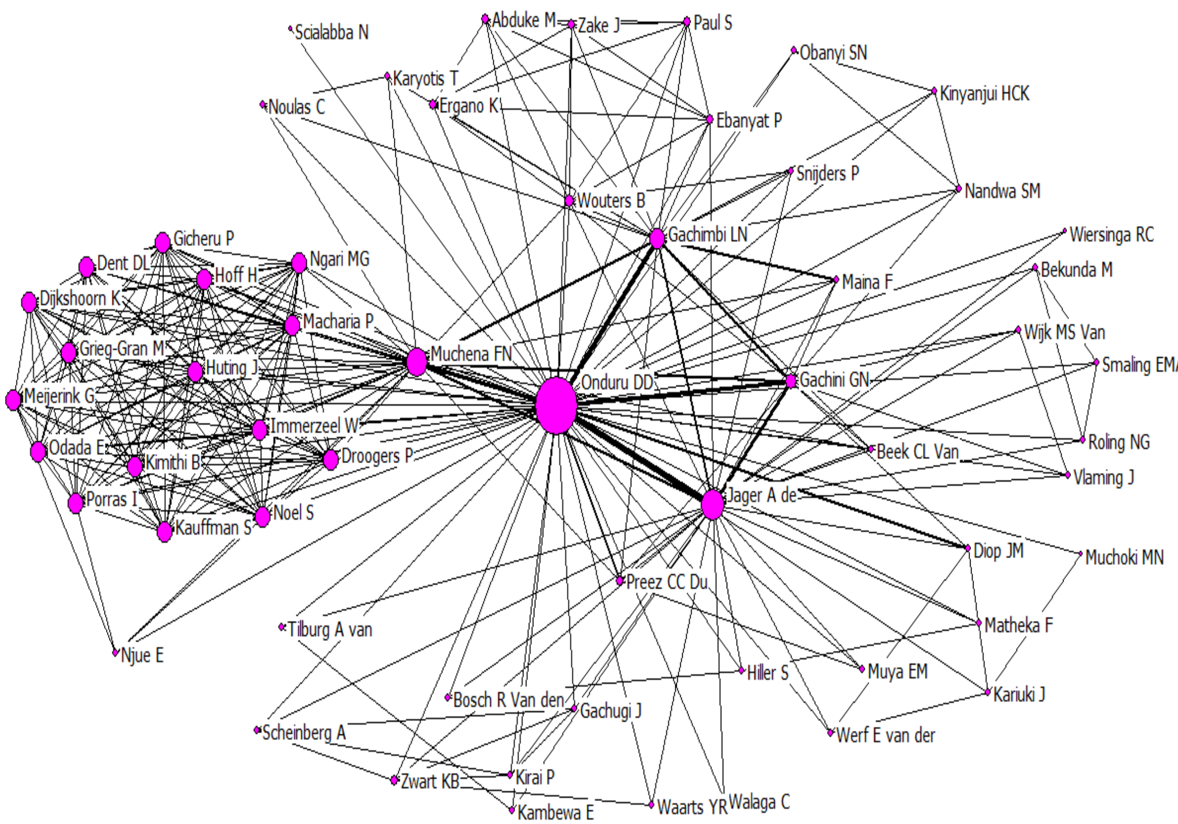


Figure 3: Co-authorship publication network based on degree of centrality measure (1993-2012)

Co-authorship and use of resources

The collaborative research resulted in my co-authored publications, some of which form part of the body of works where I was the lead author or coordinating author. However, co-authorship of publication alone is not a sufficient measure of collaborative research. Collaboration goes beyond quantifiable outputs to include intangible contributions such as ideas, motivation and moral support that shape the research process and funding of collaborative research ventures (Katz and Martin, 1997). For each collaborative research project, authorship was agreed beforehand and involved a protocol in which researchers enlisted as authors are those who had made substantial contribution to the article proposed for publication and had participated in research processes sufficiently to take public responsibility of content. I undertook the writing of the publications included in this body of works during my free time and not under costs catered for by research grant for such costs were often excluded. The publication costs were borne by my co-authors and I. However, this does not imply that researchers were paid to be included in authorship, they all had to meet the rigid criteria listed above as well as being qualified to carry out such work. My motivation to continue writing was from the desire to disseminate research results to make an impact in people's lives. Furthermore, the collaborative research process offered opportunities for me to learn from various sources including farmers and fellow researchers and aided in the dissemination of what really worked.

Although I have used co-authorship as a manifestation of collaborative and interdisciplinary research productivity, this analysis method has its own weaknesses (see Appendix 4). I did not take into account sub-authorships, persons whose contributions I acknowledged as of substantial influence, thus probably underestimating the extent of impact of research collaboration. However, a study by Laudel, (2002) reported that such persons are never sufficiently acknowledged in academic papers to make them included in the analysis as co-writers, co-authors or sub-authors. I am further aware that co-authorship in itself may not be "a complete" method of justifying research collaboration as using co-authorship is just one measure, though a dominant method of measuring impacts or productivity of collaborative and interdisciplinary research. It has been argued that there are many cases of research collaboration that are never 'consummated' in co-authored papers (Glänzel & Schubert, 2004). However, studies have shown that there is a positive correlation between collaboration in research and co-authorship giving a justification for the use of co-authorship as a proxy measure of collaboration research productivity (Lee & Bozeman, 2005). Furthermore, it has been argued that co-authorship analysis also has additional benefits of contributing to maintaining and improving researchers social relationships and understanding underlying structures of the scientific community, which is crucial for the advancement of knowledge (Umadevi, 2013).

Challenges of collaboration

Although a collaborative research process adds value to the research process, it comes at a cost and with challenges: long decision chains; untimely commitment of partners in contributing to research outputs, and the inevitable costs associated with participatory decision making and collective action, including costs of communication and negotiation. The costs are however unavoidable as they are integral part of collaborative research process which researchers have to live with but manage.

Funding and collaboration

The body of works presented here benefited from funding secured from the European Union (EU), EU member countries and/or different development partners with explicit strategies to encourage research partnerships between North and South Countries, collaborative research between national research, academic and local development agencies and/or collaborative research in public-private partnership arrangements. Application of such funds involved formulation of a joint research proposal by a consortium of research partners with one taking the position of a lead agency. However, these were competitive research grants in which the “best wins”; and we leant to be content with whatever the outcome and on many occasions living with unsuccessful attempts.

The research grants we received under this collaborative research framework enabled our participation in research that would otherwise not have occurred and carried with it the clout of credibility and public exposure, especially with the acknowledgement of such funding sources in research outputs and peer reviewed publications and in research networks. However, my experience with preparation of grant proposals is that it is an uphill task requiring hard work, research and planning. Reflecting on these research activities over the last 20 years, it is increasingly clear that national and international research grants are associated with a high-impact of donor-influenced ideas on the research agenda as application and approval of such grants must fit within the specific donor research theme and requirements. This is envisaged to minimise grant fraud, misuse and direct funding where there are societal benefits and value-for-money, but in the process acquisition of these grants becomes a lengthy process and their administration is governed by a complex set of regulations. For example, some of our research had to fit within specific research themes thus narrowing our research focus as other local and equally pressing research themes could not be funded. Therefore donor funding may influence science in a given direction, the number of publications produced in a given area of research and to some extent how research outputs are used, especially with regulations on patentable discoveries. Recent studies have similarly indicated that source of funding influences the selection of researchable themes and whether researchers publish results and patent discoveries and the manner in which they are able to do it (Hottentot and Lawson, 2012).

5.3. Contributory factors to research partnership success

Partnership composition and participation

A unique lesson I leant from the OFEA partnership was on partnership composition (see Chapter 1 and Appendix 4). In the partnership I had envisaged the participation of the national agricultural research institute as advisor and in the implementation of activities but had not included budget provisions for their participation. This limited my efforts in tapping into available infrastructure (e.g. laboratory facilities) and expertise which I needed to conduct soil analyses for assessing the differences in organic and conventional farming system performance. I have since realised that the success of partnership partly relies on bringing persons and institutions with capabilities on board and in clarifying expectations and budgets, sharing vision and dividing tasks early enough, and agreeing on modalities where each partner contributes part of their resources (financial, time and human) for the success of partnerships.

Linking research to development and markets

Another lesson I learnt was with regards to inclusion of organisations that can enhance product-value chain in the partnership arrangement. Working with farmer groups and

FFS methodology empowers farmers to access information and to adopt good agricultural practices, however, the continuity of these groups beyond the funding phase is often challenging. The inclusion of a tea buyer in the partnership on sustainable tea Project motivated farmers to continue as the market was assured. In the INMASP partnership (see Appendix 4), joint group commercial activities with linkages to local markets inspired farmers to continue with FFS activities even after the project supported “active learning phase” came to an end. Thus I came to learn that embedding value addition activities and linkages to markets in partnership arrangements can enhance and sustain development and adoption of technologies and sustainable agriculture.

Collective and individual benefits for researchers

These partnerships further shed light on costs of operationalising partnership that I did not know before. There is no consensus on how to measure costs and benefits of partnerships, though it became clear to me that research partnerships should not only have collective benefits but also individual benefits to researchers to succeed, and more so, the collective benefits need to be high to keep partnerships vibrant and strong. Although the partners described above generated collective and individual benefits to researchers and to participating organisations to various degrees, the inclusion of collective activities such as joint fund raising and formation of networks (NUTNET) and network publication series (Managing Africa’s Soils) and joint publication (Nutrients on the Move) for cross-country comparisons played key roles in sustaining LEINUTS and NUTNET partnerships. Similarly providing benefits to individual researchers in the form of funding conference presentations, facilitating researchers to produce knowledge products (journal articles, book chapters, pamphlets etc.) with consensual authorship guidelines, friendly reward systems etc. energised these partnerships.

5.4. Ethical Issues in Collaborative Research

At the time of writing I was fully aware of ethical biases frequently found in interdisciplinary and collaborative research touching on co-authorship and its implications on collaborative research productivity. These issues include: senior researchers in partner organisations using their seniority to distort authorship sequence, excluding sub-authors or susbtantive junior co-authors in the acknowledgement section and authorship lines respectively, excluding researchers who have contributed to the work but have left respective organisations at time of publishing, diluting authorship by adding more researchers in authorship lines, ignoring or by-passing agreed upon authorship guidelines, withholding data from other collaborators and from the public or manipulating data to avoid public scrutinity of results for a period of time, plagiarism when compiling publications, dublicate publications, conflict of interest that leads to distortion of results to suit funding agency interests, and treatment of human participants during research among others.

While acknowledging that ethical biases do exist in collaborative research partnerships, none of the above ethical biases manifested itself strongly in the partnership arrangements described in this context statement[20]. Co-authorship arrangements and copyrights (part of intellectual property rights) were amicably discussed in the partnerships (internal partnership arrangements) in addition to the use of benchmarks provided by journals. In addition,ethical guidelines included in research proposals and in partners' operating framework were used in conduting the research and compiling publications. However, one ethical issue that manifested itself in this partnership, albeit weakly, is the drive to publish articles in Journals with high impact factor, which in most cases have regulated readership through subscriptions and exclusive copyrights have to be transferred to the publisher. While this gave my partners and I mileage in conventional institutional research reward system, it tended to restrict public readership to those able to subscribe to the high impact Journal in question.

5.5. Collaborative Leadership in Partnerships

Leadership style

From my engagement in these partnerships it became clear that a facilitative leadership style holds the key to the success of partnerships.

[20] Ethical issues: Co-authors were consulted and were in the know on my co-authored publication preparations and submissions

My collaborators and I adopted a collaborative leadership model in the partnerships, facilitating members to work towards a shared outcome in a manner that reflects collective ownership, authorship, use, or responsibility as all participants were considered peers (Chrislip & Larson, 1994). The partnerships were organised in such a way that there was a lead partner and for each member organisation there was a Person In Charge (PI) who in turn exercised collaborative leadership with researcher-peers in coordinating the implementation of activities.

For each partnership, my co-authors and I had start up and periodic progress workshops for joint decision making processes, planning and division of tasks according to capabilities and expertise of members, reflection and clarification of expectations and sharing of experiences, successes and challenges. A facilitator oversaw workshop deliberations to build trust among partners who may at times have divergent views and conflicting interests. Partnership funds were distributed to and managed by each partner according to agreed workplans, budgets and reporting formats. This gave each partner powers to exercise authority over the speed at which activities could be implemented. Similarly, communication channels were kept open in which partners shared ideas, reports, and challenges.

I attribute the success of our partnerships and my achievements in producing this body of works to embodying collaborative leadership at partnership level but also to my personal initiatives in leading in-country and organisational teams within which I worked (transformative and positional leadership). A leadership quality was in me at a young age though I cannot say why but when I did have a leadership role for example at primary school I did it well. This reinforced my confidence and inspired me to take up leadership roles again and again in various Projects thus I gained more confidence and more skills with time. I have always enjoyed being in a position of influence to shape the direction of development and research projects but more importantly the desire to create an impact is what I love most as a leader. I have been in many situations of positional leadership making decisions and leading research groups, but this in itself does not define my full potential of leadership that led to the production of this works. On the contrary, I define leadership as an ability to make an impact on a community (e.g. on farmers researchers etc.) and to attain a goal through mutual cooperation and cohesive behaviour. In this body of works my leadership is demonstrated in pioneering systematic organic farming research in Kenya, farmer field schools in tea and adoption of participatory methodologies of research to create an impact at community level where there were none or limited experiences before (see Chapter 6). Furthermore, the facilitative, shared and transparent leadership (collaborative leadership) I adopted made the partners vibrant and open and contributed to the success of our partnerships.

It inspires me to know that smallholders with whom I worked experienced positive changes in their livelihoods in various ways through this research. This has partly contributed to their trust and belief in me as facilitator of the research process. However, gaining the respect of farmers did not happen overnight. When I started research 20 years ago none of the farmers who participated in my research initiatives knew me and my experience with smallholders was limited. Farmers watched everything that I did as a researcher, made their own judgments and in a number of cases I detected through reading non-verbal cues when they were uncomfortable or when they were satisfied with the activities that were being jointly carried out. Indeed earning the respect of farmers not only required that I adopt "people oriented skills" such as facilitation, inclusive participation, effective communication and attentive listening and neutrality in conflict resolution but also being there for them, valuing and respecting their knowledge, their contribution and perceptions even if contrary to established knowledge and also creating spaces for co-learning and generation of "new knowledge" and insights.

It has since become clear to me that my success in working with farmers and earning their respect was also due to my style of operating on the basis of trust, transparency, honesty and integrity and walking the talk, honouring every agreement made with farmers and where not possible holding mutual discussions to reach a consensus. My horizontal relationship with farmers contributed to open and enhanced participation in research, motivated them to create their own local leadership structure and common bonding activities and exposed them to other forms of knowledge through educational tours and interactions with other organisations. With time these small gestures were appreciated not only by farmers but also by extension staff and fellow researchers and partly contributed to the respect that my works and I have received in the public domain.

CHAPTER 6: IMPACTS AND IMPLICATIONS OF THE BODY OF WORKS

6.1. Background

In this Chapter I underscore the perceived and actual impacts of this body of works at farm level. For impacts at research and academia and to policy see Appendix 5. According to Walter *et al*. (2003), “research impact forms a continuum, from raising awareness of findings, through knowledge and understanding of their implications, to changes in behavior”. Thus an assessment of impact may address any point on this continuum: changes in access to research; changes in the extent to which research is considered, referred to or read; citation in documents; changes in knowledge and understanding; changes in attitudes and beliefs; and changes in behaviour among others. I used the following methods to assess impacts at farm level (i) farmer workshops at grass root level (ii) field days (iii) PTD[21] trial evaluation using semi-structured questionnaires (iv) impact assessment using semi-structured interviews and focus group discussions focusing on “before” and “after” situations.

6.2. Period 1993-1996

An important aspect of research impact is to learn how farmers have used and adapted technologies and the effects and impacts of the technologies on their livelihoods. After four years of participating in this research process (1993-1996), smallholders changed their attitude and perceptions on use of compost and double digging practices as captured during end of season evaluations, field days, focus group discussions and semi-structured interviews. By adopting these practices farmers realised increased maize yields and improvements in soil moisture retention, better looking and healthier crops.

The effects of these research processes went beyond my expectation. While we used maize as a test crop in experiments on compost and double digging, farmers discovered that these practices were also suitable for domestic vegetation production. I did not anticipate this practice but it led to reduction in household expenditures,

[21] PTD: Participatory Technology Development

increased household food availability and improved diversity of household diet. The practice particularly appealed to women farmers.

As a researcher, I felt I could identify with most of the impacts of technologies at farm level. However, there were some surprises. I had not anticipated plot-level impacts related to moles reducing the impact of double digging. Similarly, in the low agricultural potential areas, farmers changed application rates of compost in maize fields and adopted a “rotational” application to optimally use the limited available compost and to gradually fertilise their farms. Furthermore, farmers noted that the impacts of the technologies tested were to increase the number of maize cobs per plant from one to two.

6.3. Period 1997-1999

I used PTD and joint analysis workshops and visual aids to engage farmers on integrated nutrient management (INM) research. This research process demonstrated that it is possible for researchers to communicate effectively, and break the traditional distance between researchers, extension staff and farmers on INM using visual tools to translate technical terminologies into a simple language. After developing visual dialogue tools that simplified the interpretation of soil laboratory analysis and using it to dialogue with farmers I was amazed that farmers could now easily interpret the “technical” soil laboratory results, attach local meaning to soil nutrients and suggest and take action to conserve land and arrest declining soil fertility (publication 14). Farmers who initially were not using farm yard manure, inorganic fertilisers, compost and nitrogen fixing legumes and structural soil and water conservation practices changed their practices and observed an improvement in soil moisture and crop yields.

I took a neutral position in facilitating the research process leading to equitable sharing of power between research partners, extension and farmers giving space for farmers to contribute and challenge us (researchers and extension) on the workability of some technologies, e.g. green manuring. This dialogic process helped me to more deeply appreciate farmers’ as researchers with indigenous technical knowledge and criteria for evaluating technologies. They posed us research questions, shared their experiences on traditional experimentation, rejected some of our proposals[22] and offered alternatives. Consequently in one project, I moved away from experimenting with dairy animals directly and targeted closing nutrient cycles through crop-livestock interactions.

Farmers are astute and can turn a situation to their advantage. I had the idea to disseminate research findings at the end of the joint PTD experimentation process after replication in time and also during field days which the farmers believed was not necessary and was too long to wait for dissemination. They only required one agricultural season with good rainfall to be convinced and start disseminating their experiences to others through the effective social medium of visiting neighbours, attending market days and local community meetings and allowing visitors to their PTD plots.

This research process also helped them to develop their individual experimentation design, which became more systematic with improved field layouts than their traditional experiments.

6.4. Period: 2001-2005; 2006-2008

In this Section, I share the impacts of my research where I used FFS to enhance joint learning and to undertake PTD trials on integrated nutrient management (INM[23]; 2001-2005) and on enhancing sustainability of smallholder tea systems (2006-2008). I have examined the impacts by looking at the situation “before and after” intervention with FFS and by comparing research (FFS) participants with equivalent comparison groups in each study area based on data collected using semi-structured interviews and focus group discussions (see publication[24] 11; Hiller *et al*. 2009; De Jager *et al*., 2011).

The adaptations I made to the conventional IPM-FFS[25] methodology were effective. The increased duration of FFS learning cycle allowed farmers to learn a range of

[22] Ideas and suggestions on research and not conventional pre-prepared “Proposals”
[23] INM: Integrated Nutrient Management
[24] These co-authored publications also address issues on collective learning and diffusion processes
[25] IPM-FFS: Integrated Pest Management-Farmer Field Schools

practices related to INM and tea crop and increased farmer's confidence in communicating about technologies tested. The design of PTD trials implemented in five sub-groups in the tea growing catchment, rather than in a single central group plot, captured diversity and heterogeneity that exist in the tea growing catchment, allowing farmers to spread risks associated with experimenting with a high value cash crop, reduced walking distance to trial sites and ensured that labour could be organised as and when required.

I examined knowledge gains, adoption of INM technologies and Good Agricultural Practices (GAPS) in tea to explore the impacts of the FFS-based approach to research and extension. Participation in the research process significantly increased farmers' knowledge scores above an equivalent comparison group in a pre and post intervention assessment. Similarly participants in FFS attained a higher rate of adoption of GAPS and "new" INM technologies than their non-participating counterparts[26,27].

A sign of impact is when farmers disseminate the practices and technologies they have tested and learnt to other farmers. About 65-66% of non-FFS farmers in the samples interviewed indicated that they had received technical information from research participants (FFS members) indicating that the research participants were confident in the knowledge they had gained.

Yield gains and financial returns from implementation of research practices and technologies are further indicators of research effectiveness. In the research process involving INM, the majority of the farm households (> 90%) reported higher yield levels and financial returns as a result of adopting new INM practices. Among the smallholder tea growers participants (FFS members) reported 19% yield increase above the baseline and 15% higher yields than the comparison non-FFS group. The participants further cited more positive changes in their livelihoods than the comparison group

[26] INM technologies adopted: Rhizobium inoculation for legume production; *Tithonia* sp. For green manuring; composting, double digging, Tumbukiza method of Napier production etc.
[27] GAPS in tea adopted: Four plucking rounds a month; use of plucking stick; improved height of pruning, timely and better methods of weeding etc.

(total farm income, tea income, self help activities, access to information, entrepreneurship etc.).

Very importantly I assessed whether FFS activities had contributed to enhancing sustainability of smallholder tea farms using a 0-10 score scale on the following indicator clusters of sustainability: product value, social and human capital, local economy, soil fertility, soil loss, nutrients, water and effluent, pest and weed management, biodiversity and energy. The level of sustainability was high for FFS and there was a significant difference between FFS and non-FFS comparison group ($p < 0.01$; t-test).

Valuable lessons emerged from my research processes. When I initially started the FFS activities on INM and tea crop my main focus was on enhancing farmer learning for sustainability. However, I soon realised that farmers' needs go beyond technical issues and I had to adjust the FFS curriculum to include broader livelihood issues (HIV/AIDS, marketing, agro-processing, public health etc.). Similarly the FFS placed on us and the extension staff new ways of working with farmers requiring a change in attitude, a blending of indigenous and science-based knowledge and adjustment of our workloads to fit within time frames agreed upon with farmers and practice of new value-systems on facilitation and negotiation skills, conflict prevention and resolution and process documentation and team building.

Changes in behavior and attitude of farmers are among indicators of effectiveness of participatory research. Some women members of FFS who were initially shy started to express themselves during FFS meetings indicating that the FFS process had broken the cultural barriers and built their confidence. Similarly both women and men participants developed their leadership skills. Some of the participants got leadership positions in the Village administrative structures, in religious organisations and in community development groups. Although, the FFS process was appreciated by both sexes, women seemed to have especially valued the approach due to the practical, field based learning focus and the social value attached to the FFS group.

When I started the FFS process on INM and on tea crop, I did not anticipate that these efforts would culminate in building local institutions on the ground. The FFS process made the farmers build a closely knit self-help group with leadership structures, a network for knowledge exchange and support and legal identity. The groups eventually embarked on community development activities besides venturing into income generating activities and continued to meet on their own long after the research process came to an end, albeit with new livelihood activities beyond INM and tea crop.

From my FFS research, I learnt that participatory research cannot be considered an end in itself in addressing the myriad challenges of smallholders. Across all FFS groups, a need arose to initiate group income generating activities that required a kick-off fund to support farmers' livelihoods into the future indicating that participatory research with smallholders should be embedded in broader livelihood strategies to enhance impacts. This FFS research and extension methodology contributed to bridging the gap between extension services and farmers. The extension staff who were involved in the research process continued to visit the farmers who participated in the research programme, introducing other farm management practices, long after the active research phase came to an end.

6.5. Period: 2010-2012

I used my previous experience to initiate the design of an FFS up-scaling programme (2010-2012) to reach 500,000 tea growers with linkages to certified tea markets. Although we made positive progress to scale up adoption of sustainable practices in tea through an adapted FFS approach, to cover more farmers in many geographical areas, a number of lessons emerged that can inform the design of future agriculture initiatives. FFS Scaling-up requires:

(i) attention to methodology. We reduced the duration of the FFS learning cycle on tea from 18 to 12 months based on the fact that we were building on experience gained in the previous phase and we had gathered more skills and we could use PRA tools selectively to reduce the duration of the diagnostic phase and FFS curriculum formulation.

(ii) a critical mass of trained and experienced facilitators. I learnt that the success of an FFS and the speed at which it can be scaled-up is dependent on the attitude, skills, preparedness and extroversion of the FFS facilitator.

(iii) high level of support and commitment of facilitating institutions. Commitment to logistic and financial support, embedding of FFS into the activities and vision of the facilitating institution contribute to the success of the scaling-up process

(iv) market support and value added activities. When farmers are linked to buyers of certified tea and input markets and are given market assurance, their enthusiasm remains high in an FFS process. In this study inputs were availed to farmers on credit by the facilitating institution.

(v) in-built monitoring and evaluation system. This will keep track of resources and ensure that the quality of the FFS process is maintained as coverage is expanded

(v) facilitating of FFS groups to become "local institutions" complete with a leadership structure that can demand services, actively relate to other service providers and be involved in a collective action that binds group members together beyond the "active FFS learning cycle".

Up-scaling of my research and extension[28] initiatives (FFS) was a challenge. I have since realised that it can only be done at a pace commensurate with available human and financial resources with commitment to maintaining quality of the up-scaling process. It appears that no single approach can yield desired results to a complex problem of scaling up FFS and sustainable practices. There is now a need to integrate beneficial attributes of different pathways of scaling up to reduce costs and increase efficiency and coverage.

[28] In this context, the concept of (agricultural) extension refers to a set of research and farmer-educational activities that support and facilitate farmers to address agricultural sector-related constraints and to acquire, in a participatory way, new knowledge and skills on agricultural technologies for livelihood improvement. Extension is education (or outreach) aimed at bringing positive behavioural change among farmers.

CHAPTER 7: EMERGING PERSPECTIVES AND REFLECTIONS ON AGRICULTURAL SUSTAINABILITY

7.1. Determining overall direction of sustainability

In this synthesis, I have used an integrated framework that identifies key dimensions of agricultural sustainability (ecological and socio-economic), evaluation attributes associated with each dimension and key performance indicators associated with each evaluation attribute. I have compared the performance of these indicators from my various public works with their threshold values and used a scoring system to arrive at overall direction of agricultural sustainability. For details of these indicators and how they were measured see Appendix 6. The indicators are related to the following selected sustainability attributes:

- Soil quality
- Crop productivity
- Rainfall amount and distribution
- Economic viability
- Adaptability
- Self reliance

7.2. Emerging issues on sustainability

A synthesis of scores from the low-to-medium agricultural potential areas indicates a negative trend in the direction of agricultural sustainability (Table 3). This is further corroborated by exploring data on spatial and temporal dimensions of sustainability (Table 4). The performance of indicators related to soil, maize productivity and socio-economic indicators were all below threshold values derived from literature or expert knowledge. The dismal performance of farming systems in the low-to-medium agricultural potential areas continues to be a paradox. Publications I have included with this context statement have indicated that erratic rainfall patterns, poor adoption of technologies, unsound soil fertility management practices, use of poor germplasm, and inadequate investment in agricultural activities, poor input-output markets, unfavourable policy environment and “risk-aversion” are among the contributing factors (e.g. publications 2, 4, 15 and Appendix 1).

Table 3: Sustainability direction based on scores of performance in low-to-medium agricultural potential areas of Kenya (1993-2012)

Publications	Sustainability dimension	Evaluation attribute	Positive scores	Negative scores	Positive [29](% of total)	Overall sustainability direction
1,2,3,7,8,9,13	Ecological	Soil quality	3	14	18	Negative
		Maize-productivity & stability	1	5	17	Negative
		Rainfall-amount & variability	0	4	0	Negative
	sub-total		4	23	15	Negative
	-Socio-economic					
3,7,8,9,13						
		-Profitability	5	8	38	Negative
		-Adaptability	0	1	0	Negative
	sub-total		5	9	36	Negative
Overall			9	32	22	Negative

Table 4: Scores of performance on spatial and temporal dimensions of sustainability in low-to-medium agricultural potential areas of Kenya (1993-2012)

			Spatial			Temporal		
Publications	Sustainability dimension	Evaluation attribute	Positive score	Negative score	Direction	Positive score	Negative score	Direction
1,2,3,7,8,9,13	Ecological	Soil quality	4	3	Positive	1	9	Negative
		Productivity & stability-maize	0	0	Neutral	1	5	Negative
		Rainfall-amount & variability	0	0	Neutral	0	4	Negative
	sub-total		4	3	Positive	2	18	Negative
3,7,8,9,13	Socio-economic	-Profitability	1	2	Negative	4	6	Negative
		-Adaptability	0	0	Neutral	0	1	Negative
	sub-total		1	2	Negative	4	7	
Overall			5	5	Neutral	6	25	Negative

Furthermore, poverty levels are high and off-farm income is increasingly becoming important as households search for alternative sources of livelihoods in the low-to-

[29] Percentage scores are worked out for each evaluation attribute separately e.g. for soil quality in medium-to-low agricultural potential area, there are 3 positive scores and 14 negative scores (total scores 17); Thus percentage of positive scores: (3/17) * 100= 18%

medium agricultural potential areas (publications 3 and 8). However, research work included with this context statement (publications 1, 2, 3, 7, 8, 9 and 13) indicate that there is a potential to improve the performance of these farming systems using technologies within easy reach of farmers and farmer learning methodologies that enhance adoption of new innovations. I further note that technologies alone, per se may not be the panacea for enhancing sustainability of these farming systems. A supportive input-output policy framework and multi-stakeholder approach to integrated development are also required.

The gloomy scenario above, found in the low-to-medium agricultural potential areas, is in stark contrast to the situation in the high agricultural potential areas of Kenya. A synthesis of my public works indicates that these smallholders are moving in the right direction towards agricultural sustainability as aggregate scores were positive (Table 5 and 6). Contributory factors are partly historical in terms of agricultural policy implementation (see Chapter 3) but also due to moderately developed input-output infrastructure compared to other parts of the country, willingness of farmers to take risks, use of improved germplasm and favourable climatic factors among others.

Table 5: Sustainability direction based on scores of performance in high agricultural potential areas of Kenya (1993-2012)

Publications	Sustainability dimension	Evaluation attribute	Positive score	Negative score	Positive (% of total)	Overall sustainability direction
4,7,10,11	Ecological	Soil quality	9	1	90	Positive
		Productivity & stability-maize	0	3	0	Negative
	sub-total		9	4	69	Positive
4,5,7,10,11	-Socio-economic					
		-Profitability	6	5	55	Positive
		-Adaptability	7	1	88	Positive
		-Self reliance	2	0	100	Positive
	sub-total		15	6	71	Positive
Overall			24	10	71	Positive

The positive progress does not, however, suggest that all smallholder farms have progressed in the same direction. Pockets exist in the high agricultural potential areas where "negative progress" has been observed requiring continued sustainability strategies30. Sustainability is a dynamic concept and what may be "sustainable" now may not be in the future for many reasons including how an analysts defines sustainability. This therefore calls for continued observation to adapt to farming system changes as they unfold so as to take appropriate action and to enhance sustainability.

Table 6: Scores of performance on spatial and temporal dimensions of sustainability in high agricultural potential areas of Kenya (1993-2012)

			Spatial			Temporal		
Publications	Sustainability dimension	Evaluation Attribute	Positive score	Negative score	Direction	Positive score	Negative score	Direction
4,7,10,11	Ecological	Soil quality	9	1	Positive	0	0	Neutral
		Productivity & stability-maize	0	2	Negative	0	1	Neutral
	sub-total		9	3	Positive	0	1	Neutral
4,5,7,10,11	Socio-economic	Profitability	2	2	Neutral	4	3	Negative
		Adaptability	0	0	Neutral	7	1	Negative
		Self-reliance	1	0	Positive	0	1	Negative
	sub-total		3	2	Positive	11	5	Positive
Overall			12	5	Positive	11	6	Positive

I take note that the approach I have used in this Chapter to make this synthesis may raise questions regarding differences in farm performance as high performing farms may mask poor performing farms when average scores are used. Similarly, indicators I have used here are site specific. Using a two-value logic, high performing (+) and

[30] For example, in publication No. 4 I have indicated that the contribution of off-farm income to family earnings is 61% implying that the current farming system does not provide adequate entitlements to the farming households in some pockets of the study areas

poor performing (-) referenced on some thresholds or my use of progress towards sustainability (+) and no progress towards sustainability (-) as a way of assessing agricultural sustainability may raise questions. This is because sustainability in agriculture is associated with ambiguity in meaning and thus the use of multi-valued logic may offer additional insights including “fuzzy ranges of sustainability” besides my synthesis. However, despite its limitations, the two-value logic used in this synthesis was useful in gauging the direction of agricultural sustainability and painting a picture of the studied smallholder farming systems.

7.3. Linking stages of my work to emerging thinking and developments in agricultural systems and sustainability in Africa

7.3.1 Learning and innovation systems

An innovation[31] system is analytical construct for understanding system dynamics and performance and how processes of innovation contribute to farming system development and sustainability (Bergek *et al.*, 2008; Hekkert and Negro, 2009). In this Section I contextualise my works within learning and innovation system thinking based on key features of an innovation system: a focus on innovation (turning knowledge and technologies to valuable social and economic products); interaction of multiple actors with different capacities in a concerted/collective action framework to achieve common objectives, capacity development and joint learning and access to knowledge by the multiple actors; and response to institutional framework (norms, rules, laws, practices, attitudes etc.) and policies that influence the process of innovation and the way the multiple actors relate with one another (The World Bank, 2006).

I have adopted technological innovation systems approach, introduced by (Carlsson and Stankiewicz, 1991) to reflect on my public works in the period 1994-1999. In this period, my partners (including farmers, Appendix 4, Table 4.1) and I focused on the generation, diffusion and utilization of low external inputs and organic farming technologies (new to some partners and to framers) exploiting the opportunity presented by high inorganic fertiliser costs. Reflecting on this innovation system, a number of strengths, challenges and weaknesses emerge. The innovation system had knowledge development platforms (e.g. through learning by doing), avenues for knowledge diffusion (e.g. regular meetings with farmers/community meetings), memorandum of understanding, joint workplan development and privileged farmer involvement in all stages of research process. This changed the way research was done (see Chapter 2) and our thoughts and attitudes changed too (see Section 4.3.2). However, this innovation system did not have a private entrepreneur in the network of actors (thus "partial innovation system") to turn the technologies (e.g. compost) into business opportunities other than farmers using the technologies for on-farm self-reliance.

I further apply the concept of innovation system to reflect on the innovation of "bridging livestock-nutrient cycles through small scale milk processing and value addition" in the period 2001-2005, an off-shoot from INMASP Project (see partners in Appendix 4, Table 4.1). The trigger to the innovation system was the knowledge gained by actors during FFS interaction: poor fodder and manure use and low milk production and low milk prices and the national policy on milk market liberisation in Kenya. The various partners contributed unique strengths (e.g. knowledge and skills) to make the system work and had joint learning platforms (learning by doing and in scheduled meetings). Though, there was no entrepreneur/private sector in the "network of actors" to turn the knowledge/ideas emanating from this innovation system into "business", the FFS members registered with relevant Government Department, initiated small-scale milk processing and mobilised local resources with assistance of partners to make the milk processing work and to disseminate knowledge on the importance of sound soil fertility

[31] Innovation-refer to the search for, development, adaptation, imitation and putting into use of technologies, approaches and methodologies that are new to a specific context and that have social and economic significance, irrespective of whether they are new to others, to a country or the world (The World Bank, 2006; Sanginga *et al*., 2006).

management for high fodder production and thus enhanced milk production. I have since learnt from this innovation system the important role played in working with farmer groups, in this case FFS group, in building structures to sustain an innovation system. The opportunity to market their milk and to generate income propelled the FFS members to continue beyond the project period and thus sustain the innovation process.

I further frame my works in the period 2006-2012 within an innovation system where my interaction with a network of public and private actors and smallholder tea growers enhanced adoption of good agricultural practices in tea and smallholder tea certification for international market (see publication 11 and Chapter 5. My partners and I learnt together, had a memorandum of understanding and shared knowledge, experience and expertise through various fora: farmer field schools, project meetings and in conferences, technical and steering committee meetings and in study tours etc. The trigger to the innovation system was increased opportunities for enhanced incomes through enhancing tea productivity and access to niche markets through Rainforest Alliance Certification. Reflecting on my works, I have since realized the importance of having a tea buyer and a certification body (e.g. Rainforest Alliance), to increase smallholders' access to niche markets.

7.3.2 Linking my works to multi-stakeholder processes

Multi-stakeholder processes[32] are interactive processes that bring different stakeholders into working together, constructive engagement, dialogue and decision making and joint learning on a situation that affects them resulting in a collective action (Wageningen UR Centre for Development Innovation, 2009). In this section I have used the concept of multi-stakeholder process (MSP) and platforms to make linkage to various stages of my works. I conceptualise my works in the periods 1994-1999, 2001-2005 and 2006-2012 as forms of engagement in multi-stakeholder processes: OFEA/LEINUTS, INMASP and Sustainable Tea (Appendix 7). I further used this concept to reflect and investigate the "processes" and the "collective action outcomes" of each of the MSPs and to generate lessons I learnt (see Appendix 7). I have presented triggers for this MSPs in Appendix 4.

Reflecting on the various multi-stakeholder platforms, I now realize why we had more learning opportunities in platforms that used FFS (INMASP; Sustainable Tea) than those that did not (OFEA/LEINUTS) and also in platforms with technical and steering committees (Sustainable Tea) than those that did not. The option of a technical and steering committee independent of the lead institution functioned well, avoiding conflict of interest and promoted enhanced interaction among partners through laid down norms and rules of working together and over time, built trust. At field level, all partner activities coalesced around the community groups (FFS, research groups etc.), guided by jointly developed norms of operations (FFS learning norms), jointly developed calendar of activities and or FFS curriculum.

In the sustainable Tea multi-stakeholder process, my partners and I started with a curriculum which was agro-technical based, but in the process of interactions learnt

[32] It is based on the assumption that knowledge emerges, innovation occurs and new ways of dealing with problems are found and turned into action as individuals and groups work together towards a shared aim and a collective action.

that farmers interests go beyond technical issues into broader socio-economic and livelihood issues (see publication 11) and through consensus the curriculum was adjusted in joint discussions. In OFEA/LEINUTS platform, my partners and I had an oversight and did not include District policy makers/stakeholders in the platform early enough. Though we organised District policy/stakeholder workshops towards the end, the workplans and the development scenarios mapped out by district stakeholders were not followed up beyond the lifespan of the multi-stakeholder platform due to short project lifespan and inadequate fund allocation.

My experiences with these multi-stakeholder processes were that they achieved two forms of learning: instrumental learning that changed behavior of stakeholders and resulted in development/adoption of sustainable agricultural practices; and emancipatory learning (capacity development and people's ability to contribute). Similarly they enhanced understanding of key issues of focus in each platform in addition to building trust and improving relations among stakeholders and enhancing smallholder tea farmers' access to niche markets (see Appendix 7).

I have presented factors hindering and or facilitating multi-stakeholder forums (OFEA/LEINUTS, INMASP and Sustainable Tea) in Chapter 5, Appendix 4 and 5. It is my view that these stakeholder platforms were established around projects and programmes and were therefore time-bound. Although this does not present a problem since a multi-stakeholder process must have a time frame of operation and undertaking a collective action(Woodhill, 2004), quite often they require continuous monitoring and evaluation of performance beyond the set time frame.

7.3.3 Embedding my works in capacity development framework

In this section, I elaborate on how I used and applied capacity development[33] concept when undertaking my research work, vis-à-vis recent developments and current thinking.

In early years of my research (1993-1996), my focus was to strengthen skills, competencies and farmer abilities. I understood capacity building as a stepwise procedure where capacities of rural farmers are increased over time through periodic trainings and or interaction with farmers. However, I have since learnt from evolving literature that capacity building is a process and not training events and that it is iterative and does not take linear form. Thus currently, the term capacity development is preferable to the step-wise notion created by the use of "capacity building" or "capacity strengthening" as I understood it in my early years of research (OECD, 2006; The World Bank, 2011).

My activities in capacity development, over the years in my research practice, has had a focus at two levels: at the level of "facilitating" research partnership organisations and at community level with smallholder farmers. At the level of facilitating organization, my partners and I had a strong focus on enhancing capacities of "researcher individuals" within partner organisations in funded projects (1994-1996; 1997-1999; 200-2005). I have since realised, in line with evolving literature, that

33 Capacity building- a process by which individuals, groups, organisations and societies increase their abilities to (i) perform core functions, solve problems, define and achieve objectives; and (ii) understand and deal with their development needs within a broad enabling environment (institutional arrangements, policies, legal frameworks etc.) and in a sustainable manner (OECD, 2006).

modern thinking on capacity development is move away from a narrow focus on knowledge and skills required by individuals and organisations through short-term trainings/workshops to a broader view that focusses on long-term continuous processes and goals beyond event-based trainings to a focus on ability to perform at three interdependent levels-individual, organisational and enabling environment (broad political and social context) and to bring a change in values and behaviour (institutional change) (The World Bank, 2005; OECD, 2006; CHF, 2007).

At farm level I used farmer research groups and farmer field schools as a framework for capacity development (e.g. see publication 11), in tandem with modern day thinking on capacity development: a process where local communities develop requisite skills and expertise to manage their environment and natural resources in a sustainable manner through strengthened abilities to achieve sustainable livelihoods, technological change and innovation and building social capital through experimentation and learning and developing skills (soft and hard[34]) of performance in a multi-disciplinary framework (UN, 1996). Similarly, modern view on capacity development agrees with the way I employed FFS as a capacity development strategy: centred it as an endogenous change (Pearson, 2011) and life-long learning process of which training is just a component (McMurray, 2011); made a shift from supply to demand-driven approach in which farmers' priorities are paramount (LenCD, 2014) and used it as a two-way learning process where learning for change takes place within the learner and learning and development is "not done for them"(Hunt, 2005) but is focused on co-creation-of- knowledge model.

Another modern thinking on capacity development is that it is a long-term complex change process (complex adaptive system) that is continuous and brings changes in behavior patterns, knowledge and motivation (The World Bank, 2005; CHF, 2007). This partly contrasts my initial understanding of duration of capacity development efforts based on technical cooperation programmes (North-South partnerships) that I was involved in, lasting between 3-5 years. Although there is no blue print on how long capacity development efforts should last, the problems of short duration cycles are well documented and a 10-year horizon has been recommended by other authors based on the fact that agricultural systems change slowly (Hudson, 1992).

In activities carried out to support capacity development, the area of knowledge exchange[35] is increasingly being mentioned. Knowledge exchange is a concept that stresses that practioners (researchers, academia and other actors) go beyond knowledge generation, training, knowledge products and technology to share practical or experiential learning, and knowledge with others in various fora (platforms, networks, customized consultation visits, peer-to-peer exchanges, collaborative research, seminars, workshops etc.) for replication elsewhere, build coalitions for reforms and promote open development (The World Bank, 2011). Reflecting on my research practice and the concept of knowledge exchange, I can now identify areas

[34] Hard capacities: Material resources- infrastructure, technologies, information systems, financial resources, personnel etc.

35 Effective knowledge exchange involves interaction between decision-makers and knowledge generators (e.g. researchers) and results in mutual learning through the process of planning, producing, disseminating, and applying existing or new research in decision-making.

where I participated in knowledge exchange: District policy workshops drawing participation of various stakeholders (see Appendix 5); two networks (North-South arrangements), NUTNET and Enhancing soil fertility in Africa: from field to policy maker (see chapter 4 and 5), various workshops and scientific conferences and in farmer field school platforms.

7.3.4 Using political ecology analysis to frame my public works

(i) Political Ecology of land and soil fertility decline and my works

Political ecology (PE) is the study of the linkages between society, political economy and the environment and provides the tools for understanding human-environmental relations that shape environmental change (Blaikie and Brookfield, 1986; Adger *et al.*, 2001). It traces drivers of environmental change to larger political and economic context away from local site (place-based) where the problem is perceived to occur and puts emphasis on multi-scale analysis (Engel-Di Mauro, 2009). In this Section, I frame my works in this interdisciplinary field and introduce “specific lenses” and assumptions in PE that guided my works.

Political ecology assumptions and my public works

I situate my works on four principal assumptions and perspectives in political ecology, which I share with many authors in this field: integrated analysis of social, and economic (and political) dimensions of environmental change based on place-based research and methodological pluralism (Paulson and Gezon, 2004); multi-scale analysis (Robbins, 2012); access and control over resources and social relations of production (Paulson and Gezon, 2004); and participatory and practical political ecology for alternative development (Rocheleau, 2008).

Political ecology of organic-inorganic resource use

A characteristic of political ecology studies is the inclusion of wider political economy and multi-scale analyses. My drive to use low-external inputs resources (e.g. organic manures) was partly influenced by “non-place based” forces: Structural adjustment programmes and the Kenya Government intervention in the fertilizer sector. One of the impacts of the macro-economic forces of structural adjustment programmes was to increase the prices of inputs beyond what farmers could afford and to decrease public services in the rural areas and thus the use of organic inputs was plausible alternative for smallholders. Similarly, in the period 1991-1994, the Government of Kenya carried out a number of reforms in the fertilizer sector (see Chapter 3) resulting in increased availability of fertilisers. However, disparities still existed in the use of fertilisers between large scale farmers, using most of the inorganic fertilisers, while small-scale farmers using mainly organic fertilisers and very little to nil inorganic fertiliser due to prevailing high inorganic fertiliser prices. Thus, my research focused on the use of organic-inorganic combinations and organics which smallholders could afford.

Practical political ecology and my works

Practical political ecology (PPE) looks at a more solution-oriented research agenda involving action research, collaboration with grassroots groups (NGOs, social movements), “participatory democracy” in action, working with networks of producers and consumers, and linking environmental conservation to social justice and certification of ecologically "sustainable products (Organic, Fair Trade[36], UTZ Certified, Rainforest Alliance Certified etc.) to advocate for alternative forms of agricultural sustainability, broader sustainable development and new ways of doing politics without state power (Rocheleau, 2008; Sridhar, 2010). In this respect, local context and philosophy of a social movement (IFOAM[37]), and environmental certification body (e.g. Rainforest Alliance) further inspired my works on low external and organic agriculture, and sustainable tea production respectively (see publication 11). Reflecting on my public works and using practical political ecology as a lens for analysis, I now believe that many other worlds are possible and practical: participatory research methods can be used to bridge the gap between theory and practice, co-generate knowledge, and motivate farmers to adapt to changing conditions and to close knowledge-action gaps

Political ecology of global narratives and my works

In this sub-section, I examine received wisdom and dominant "political" narratives (discourse) that inspired my public works and use the frame of political ecology to understand environmental change.

A common thread of these narratives is to establish a link between population growth and natural resource degradation along the lines of Malthus theory (Malthus, 1826). Similarly they make linkages to poverty. For example, (World Bank and FAO, 1996) have advanced the argument that:

"*The nexus of rapid population growth and high population densities, low productive agriculture, and depletion of natural resources has created negative synergies that exacerbate existing conditions of soil nutrient mining and underdevelopment, thus creating a vicious cycle of poverty and food insecurity"*

Without suggesting that there are no hot spots of degradation, I question the on-going narrative in my publication No. 15. Similarly, the work of (Tiffen *et al.*, 1994) and (Leach and Mearns, 1996) have also adduced evidence that rising population pressure may not necessarily be the precursor of land degradation in Kenya and other parts of developing world. I have since realised that these narratives are persistent in policy circles because of the popular world view, deeply rooted in undisclosed political and economic interests.

Another thread in these narratives on land degradation that inspired my research is that which presents soil fertility as a managerial and technical challenge, a quote from (Sanchez *et al.*, 1996, p. 3) and that from (Smaling *et al.*, 1997, p. 50) , illustrate these views:

" We have concluded that soil-fertility depletion in smallholder farms is the fundamental biophysical root cause of declining per capita food production in Africa, and soil fertility replenishment should be considered as an investment in natural resource capital…. By fundamental root cause, we mean that no matter how effectively other conditions

[36] Fairtrade certification is a product certification system based on a standard that meet certain environmental, labour, and developmental standard. It is driven by the belief that not all trade is fair. Fairtrade enables consumers to put this right by to addressing imbalance of power in trading relationships, unstable markets and the injustices of conventional trade.

[37] IFOAM: International Federation of Organic Agriculture Movement

are remedied, per capita food production in Africa will continue to decrease unless soil-fertility depletion is effectively addressed" (Sanchez *et al.*, 1996, p. 3).

"Nutrient depletion is quite severe in the soils of SSA and estimates of net losses were of the order of 22 kg nitrogen, 2.5 kg phosphorus, 15 kg potassium per ha per year" (Smaling et al., 1997, p. 50)

I have since learnt from political ecology that processes of environmental change and their drivers are not neutral and therefore, cannot be considered to be a problem of technical management only or blamed on proximate local forces (e.g. poverty) (Robbins, 2012). Rather the causes are "place-based" and "non-place based" with land degradation and soil fertility decline resulting from intersecting and conflicting economic, social and ecological processes operating at different scales (Taylor, 1999). This is further explored in my publication No. 15.

Though these narratives contributed to shaping my works on agricultural sustainability (see publications 3, 4, 8-11, 14, 15) and in getting research funding, which my partners and I justified on the basis of these narratives my reflection on these narratives has since revealed that their empirical roots are rarely questioned in literature, they have been taken in policy circles as the norm and have been dominantly taken a biophysical perspective, presenting land degradation as a managerial and technical challenge with little attention to social context.

(ii) Environmental entitlements and my public works

Political ecology shed light on how farmers' capacities and incentives to invest in sustainable land management are shaped by differential resource access (land, labour, knowledge, technology, transport and livestock) and control as mediated by institutions, policies and social differentials in power relations rooted in class, gender, race and ethnicity (Paulson and Gezon, 2004; Ramish, 2010). In this section I explore the dimension of access and control over resources as mediated by institutions under environmental entitlements approach.

Environmental entitlement approach[38] shifts explanation on how environmental degradation takes place from perceived direct poverty-environmental linkages and from aggregate population pressure on limited resources to a focus on institutions that influence ecological change by dictating how socially positioned actors in a society gain access, control and management of natural resources to secure their livelihoods and in the process "alter the state" of the environment (de Haan, 2012). In this section, I reflect on how the smallholder farmers whom I worked with gain access and control over land based resources and thus secure their livelihoods as mediated by formal and informal institutions in my research sites and how these institutions have shaped the process of change on agricultural land quality.

In my research sites, land and agricultural land-based resources and entitlements are often contested by different community actors from pre-independence times with formal and customary rights and obligations working alongside each other and

[38] The Entitlement approach explores the politicised and conflicting nature of human-environmental relations by explaining how differently positioned social actors command environmental goods and services that are instrumental to their well-being (Bohle *et al.*, 2000).

sometimes at cross-roads to confer various land tenure systems and mediate on how various actors gain access to land-based utilities and what activities they can carry on land to conserve it.

In the patriarchal systems in my research sites, access and control over land is gained through sons bequeathing from their fathers. This customary based control and influence has led to situations where land and land-based resources becomes fiercely contested upon the death of the "father-figure" with household actors avoiding sound land management practices and long-term investments in land until they are assured of long-term land use rights on such land parcels (tenure security). I now concur with some previous studies on the same indicating that secure land tenure dictates whether land conservation practices will be implemented, including planting of drought tolerant vegetation, and that:

"*Soil bunds are likely to be constructed where land rights are more secure and not under common property resources*" (Kabubo-Mariara, 2007, p. 30).

I have further observed that the insecurity of tenure coupled with customary practices in some parts of my research sites ban rural women from making long-term investments on land such as planting trees and or making terraces. This situation is similar for leased land irrespective of the gender of the land manager. However, in situations where there is tenure security (formal or customary) I have observed households practice long-term investments on land conservation practices like like structural soil and water conservation practices, planting of agro-forestry trees, construction of fences; and they have been managing land with a long term perspective. My views have been corroborated by studies done elsewhere in Kenya which have reported that households with long-term tenure security, as conferred under free hold, invest in long-term land conservation practices (Kabubo-Mariara, 2007).

The entitlements approach has increased my understanding of how people gain access to and control over resources as mediated by formal and informal institutions. However, I agree with other authors that it is too much concerned with local level dynamics and fails to incorporate larger economic trends and other scales of analysis (Cramer, 2000).

CHAPTER 8: CONTRIBUTION TO KNOWLEDGE AND PRACTICE

Integrating, Participatory, Bridging, Adapting, Assessing

8.1. Integrating

I integrated biophysical, spatial and temporal studies with socio-environmental and socio-economic aspects along with the participative methodologies in capturing the voice of the farmers and their actions in agricultural sustainability assessment, an approach that has not been widely used in Kenya to assess agricultural sustainability. By adopting an integrative approach, I challenge the view that agricultural sustainability can be evaluated as partially sustainable or conditionally sustainable without taking full cognisance of the various inter-related factors that affect sustainability. In adopting this method of integrative assessment, I have changed over time in my perspectives from this novice practitioner and researcher focused on soil parameters to a holistic researcher (and in so doing become fairly unique) that takes a complete view of sustainability from the perspective of the farmer and other practitioners.

I have made a contribution to knowledge and practice by conducting research that presents an overt linkage between organic farming theory and practice and a pioneer research effort to explore organic farming viability and sustainability in Kenya. To the best of my knowledge my publications 6, 7 and 8 were pioneer work on evidence-based and field based systematic research on organic farming conducted together with farmers in Kenya in the period 1993/1994 to 1999. Results of these studies challenged the hypothesis that organic farming is more suited to high agricultural potential areas than low agricultural potential areas. In low agricultural potential areas organic farming proved equally competitive.

8.2. Participatory

This body of work further generates knowledge and contributes to community of practice on the development and application of participatory approaches to agricultural sustainability research in Kenya. I used participatory and action research methodology at a time (early 1990s) when the use of participatory research was just emerging at the national research systems in Kenya and there was limited knowledge on its suitability (see Chapter 3 and 4). I adapted participatory technology development (PTD) principles and fine-tuned the methodology to target resource poor farmers thus distilling unique lessons for Kenya and for the region (publications 6 and 7, Diop and Onduru, 2000), widened the scope of PTD to include multidisciplinary teams and multi-institutional participation, created fora where farmers engaged district policy makers and facilitated the development of vertical and horizontal linkages. These experiences formed my basis for continually improving and adapting the methodology in subsequent research initiatives (public works Nos. 4, 9, 10, 11 and 12 and other co-authored publications e.g. De Jager *et al*., 2004 and De Jager, *et al*., 2011).

8.3. Bridging

Bridging communication gaps between “hard science” and “soft science” in farmer learning on INM and agricultural sustainability is innovative. In publication 14, I present a methodology on how to undertake participatory characterisation of soils with farmers, bridge farmers and researchers’ knowledge and communication gaps on soil fertility and how to translate the technical terminologies of soil nutrients when giving a feedback to farmers on soil laboratory analysis. I further contributed to bridging communication gaps between scientists and farmers on INM by adapting PRA[39] tools to make observational and visual aids suited for farmers to diagnose farm nutrient flows, identify soil fertility constraints and explore local solutions to addressing them. These tools include adapted pictorial nutrient flow mapping, thematic participatory soil mapping, transect walks, problem trees, farming system diagrams and seasonal calendars. The application of these tools to integrated nutrient management has been variously described in my other co-authored public works (De Jager, *et al*., 2001;De Jager *et al*., 2004).

By bridging science-farmers knowledge bases through improved communication, I had the opportunity to develop technologies that suit farmers socio-economic circumstances and biophysial environment; and to enhance technology uptake,

[39] PRA: Participatory Rural Appraisal

refinement and dissemination. These initial beginings triggered other research work on developing communication tools on soil fertility management in the region.

8.4. Adapting and Assessing

I have further advanced the current knowledge bases on sustainable agriculture by adapting the use of (FFS) learning approach, resulting in a new and adapted FFS methodology that builds farmers and extension workers skills and capacity to enhance agricultural sustainability in dairy-perennial crop-based farming systems (publication 11) and on soil quality and integrated nutrient management (publications 9, 10 and 12). The new and adapted methodology was a pathfinder that presented a departure from the use of FFS on integrated pest management in annual crops only, reaching a few groups of farmers, to a new and a flexible approach capable of being used to enhance agricultural sustainability on diverse farming systems; and to up-scale pilot initiatives to many geographical areas and to many groups of farmers, creating similar impacts, within a comparatively shorter time period.

An assessment of an agricultural system cannot capture all dimensions of sustainability to the same depth and breadth. I applied two innovative decision support systems, NUTMON (Vlaming *et al*., 2001a) and QUEFTS model (Janssen *et al*., 1990) to bridge the existing gap in knowledge on nutrient balances and farm performance between seminal studies done at continental level and studies done at lower spatial scales, farm level. Using NUTMON model, I captured smallholder farm management strategies and their impacts on farm nutrient balances and financial flows under different socio-economic settings in a holistic and integrative manner and provided information on the level of sustainability of smallholder farms (publications 3, 4, 8, 10, 11 and 12). However, after several years of applying NUTMON model spanning the period 1997-2005, my experiences showed that the model demanded high skilled labour inputs for refining required model transfer functions, data collection, debugging and processing of outputs; and there was always a time mismatch between its application for farm diagnostics and the use of model outputs. Subsequently my co-authors and I piloted the adaptation of the NUTMON model to a quickscan tool for farm diagnostics (period 2001-2005; publications 3, 4 and 10) and later (2006-2012) into a new tool, MonQI (Monitoring for Quality Improvement) which I used to initiate joint learning on sustainable tea production and certification (publication 11).

My major limitation with the application of the NUTMON and MonQI models were their static nature. They are not suited to making simulations for future scenarios of nutrient and farm economic performance and agricultural sustainability. This limits the applicability of the models in gaining insight into long-term effects of farm management on productivity and sustainability. There is need to create linkages with dynamic models to simulate effects of farm management practices in time and in space, for example the use of NUANCES model that integrate farm-scale resource management simulator FARMSIM (Tittonell *et al.,* 2007), using bio-economic models based on multiple goal linear programming (Hengsdijk & Kruseman, 1992) and using adds-to NUTMON to integrate dynamic aspects (Stoorvogel, 2007) among other options. This option, however, will require extensive data collection and model calibrations in different farming systems.

Besides NUTMON and MonQI models, I applied Quantitative Evaluation of the Fertility of Tropical Soils (QUEFTS) model to predict attainable on-farm maize yields from soil chemical indices, nitrogen, phosphorus and potassium (publication 2). The model has been described in Janssen *et al*. (1990). My experience with the model was that it was simple, able to predict maize yields, calculate yield gaps and attach a financial value to such gaps. However, I was not able to observe a significant correlation between farmer's actual yields and the models prediction. I postulated that this could have been due to other yield reducing factors not currently included in the model such as climate and management factors. The inclusion of such factors may enhance the use of such models in the future. Similar application of the Model to cereal crop systems in Uganda also observed that the QUEFTS prediction tended to be higher than actual observed yields and suggested that other nutrient limitations besides nitrogen, phosphorus and potassium and other soil physical aspects could have contributed to the disparity observed (Ebanyat, 2009).

CHAPTER 9: CLOSING COMMENTS

Conducting participatory research on soil fertility management and on various dimensions of agricultural sustainability have contributed to shaping my present day perspectives on sustainability of smallholder farms. I now believe that the smallholder farms are remarkably more persistent and resilient than my earlier view that they can be potentially out-competed by the capital intensive large farms. Furthermore, it has become clear that opportunities do exist for smallholders to be key drivers of food production and improvement of rural livelihoods if declining soil fertility can be addressed through holistic and integrated approaches that take into account ecological, social and economic dimensions of agriculture. Additionally working in multidisciplinary teams and using participatory approaches makes research and development efforts more fruitful with wider impact. Participatory research demonstrates that local people (smallholders) are knowledgeable, and that they, together with researchers, can jointly work towards analyses and solutions. As I document my experiences and activities in which I have been involved, I realise the personal and professional value of working with smallholders and addressing issues of sustainability at local national and international level, including policy processes. There are strong indications that these field experiences have changed the perspectives of the smallholders, the researchers and other development workers, one such indicator is that at my workplace participatory research has been mainstreamed.

When I was appointed a researcher with one of the Non-Governmental Organisations in Kenya to investigate viability of organic farming practices at farm level to collect data that can inform policy and future research, and to compile practice-based reports and other publications for dissemination of research results to extension and to the research community, I was ecstatic but I never knew that this was the beginning of a long journey that was to open doors to do what I have always wanted to do, conduct "empowering and emancipatory" participatory research with farmers on smallholder agriculture to bring a difference using methods at the interface between bio-physical and social sciences.

In pursuit of this vision and commitment, my research journey over the last 20 years, has resulted in a portfolio of public works largely in the form of peer reviewed documents (journal articles, book chapters etc.) and lived research methodological experiences based on collaborative research partnerships that focused on knowledge generation, action (implementation) and dissemination. So when I heard about this doctoral programme I grasped the opportunity to reflect on these public works and my personal development as a researcher, critique methodologies used, examine my epistemology, bring out overarching messages on agricultural sustainability based on my research work and examine my contribution to professional practice and to academic knowledge generation; and reflect on the impacts which my works have had on development of smallholder agriculture and on the extension, research and development community.

This doctoral pathway provided me with opportunity to blend an academic research doctoral model with professional practice based knowledge, skills and competencies. In this regard I have been able to produce works equivalent to PhD by thesis with the added advantage that my different forms of evidence have been recognised and legitimised. Indeed the programme recognised all my relevant works thus reflecting my research practice, professional development and what I stand for in life in a holistic manner. The recognition of my peer reviewed journal articles and other research portfolio contributed to acceptance of the authenticity, accuracy, validity, reliability and credibility and generalizability of my research results and their impacts. However, I admit that the process of writing the Journal articles was characterised by multiple revisions and sometimes took too long to be completed in the peer-review system. I did not mind this though, it gave me the opportunity to clearly state and defend my results.

When I first started on this programme, I had not heard about reflective learning and reflective writing styles as my early training in agricultural and natural related sciences and writings had been firmly rooted in the “impersonal voice” and natural science writing styles characteristic of such disciplines and associated journals in which I published my works. Thus, I had a slow start in putting this context statement together. However, the available literature on reflective learning and the larger goals of this programme convinced me to continue on and surprisingly, the more I reflected on my public works the more I found myself enjoying and writing using personal voice to create meaning and learning from the process of reflection. The reflective writing style underpinning this programme enhanced my awareness of my thoughts and research activities and theories-in-use that shaped my research practice and academic and professional development. For example I had always believed that knowledge on agricultural sustainability is created through pragmatism but had previously not thought that personal reflections and the process of doctoral-write ups would lead me to self-discovery, and uncover new dimensions of learning and opportunities to question what my beliefs are and *why I have been doing what I have been doing* in my research practice. Furthermore, this doctoral pathway created opportunities for me to make linkages between my various publications and to illuminate cross-cutting issues and knowledge that would otherwise have remained hidden from untrained eye or treated as applied personal knowledge unexposed to the public. It has indeed encouraged me to identify emerging issues and direction of agricultural sustainability from my public works.

I used the opportunity provided in this programme to engage in further "meaning-making". By reflecting on my public works and synthesizing them for cross-cutting methodological and theoretical roots, the doctoral programme inspired me to clarify my ontological and epistemological positions in relation to my research practice, bridge gaps in my public works, make explicit my underlying thinking in producing this body of works and to identify weaknesses and strengths for further improvement of my research and development practice and personal growth as a researcher. Indeed from my experiences as a field researcher over the last 20 years, it has become increasingly clear that my personal satisfaction and development as a researcher is closely intertwined with success and development of smallholders with whom I work. Where we had "research success", I saw the smallholders championing the research results, trying them out, sharing them and having new ways of looking at agriculture. Where we had no quick fix, we both perceived our worlds as being challenged.

This doctorate pathway further provided an opportunity to challenge my thoughts and position my works in international literature to complement existing literature in my works. Though my published works already had some literature that provide intellectual context and situate them in the field of agricultural sustainability when writing this context statement I identified a need to further strengthen this foundation by incorporating additional literature to bridge knowledge gaps, identify distinctive contribution of my works and identify other researchers in my field and support, with similar works, emerging facts and opinions.

In reflecting on this doctorate programme, I have realised how my previous experiences, from the time I was a child, have contributed to my practice as a researcher that questions the basis for existing practices in agriculture. Indeed through reflections on my life experience during this study, my perspectives on my research practice and other life domains I feel I'm a changed person. I have re-discovered myself as an autonomous learner, found linkages with my research and career interests and learnt to frame my research experiences as forms of personal, professional and academic growth. I'm looking forward to improving frontiers of my research practice in the future as my life unfolds.

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Appendix 1: Agricultural Sustainability and Food Production

1.1. Introduction

Sustainability of small farms is increasing gaining attention worldwide. The question on the research and development agenda is whether these smallholder farms are sustainable and whether individually or as a group they contribute to sustainability objectives (Aid, 2011; Missereor, 2008; Ikerd and D'Souza, 1996). The principal theme, therefore, of these submissions is on assessment of agricultural sustainability. Sustainability is a visionary paradigm converging between the three pillars of economics, social equity and environmental protection (Drexehage and Murphy, 2010). The term sustainability has been applied to many areas of development including agriculture and environment despite the fact that its definition remains elusive. Increasingly research and development recognise the importance of sustainability of agricultural systems and the need to develop appropriate methods to measure agricultural sustainability. However, sustainability of agricultural systems is a debate in the public domain, partly due to the fact that it is essential for transition to sustainable development and partly due to the fact that "sustainability" defies a consensual definition (UNCED, 1992; WSSD, 2002).

In the on-going debate, the concept of sustainability appears to be used in various settings and in various disciplines to drive the research and development agenda. In these settings, sustainability has been conceptualized as the ability of a system to maintain itself into the future. Applied to agriculture, most researchers and development workers subscribe to the fact that a sustainable agricultural system uses resources to produce food, feed and fibre in such a way that the resource base is conserved and that the basic needs of producers and consumers are met over the long-term (Smit and Smithers, 1994). However, it is noted here that despite a consensus on the concept of sustainability, its definition and application to agriculture and development, and how agricultural sustainability can be measured remains contested in policy discussions, in research and in practice (Smit and Smithers, 1994). In particular, the lack of a consensual definition has led to the questioning of the usefulness of the concept of agricultural sustainability (Hansen, 1996). This is partly because agricultural sustainability assessment is likely to be influenced by evaluators' subjective judgments; definition of agricultural sustainability adopted; the fact that sustainability has no single summary indicator and many site-specific factors need to be taken into account; and the necessity to 'either/or' a combination of a multidimensional perspectives (i.e. social, economic and ecological) and multi-functional perspectives (e.g. food security, biodiversity and natural resources conservation, maintenance of the landscape) for agricultural sustainability assessments (CEC, 1999; FAO, 2005). Furthermore, there are many other factors that influence agricultural sustainability such as scale of studies (field, farm, village, catchment, etc.) and whether studies have been undertaken in space (spatial dimension) or in time (temporal dimension). However, it is this vagueness in the concept of sustainability that gives this body of works its strength because "it does not restrict the research field too much, and, in turn gives freedom…..to explore wide, unknown domains" (Lichtfouse et al., 2009, pg 4).

Since the definitions and approaches to sustainability and sustainable agriculture remain contested, the introduction to this Context Statement, at the outset, explains the concept of agricultural sustainability, presents the on-going debate on agricultural sustainability, competing views and describes factors and trends that underpin the drive towards agricultural sustainability in sub-Saharan Africa to frame it within the wider context on which this body of public works was produced. This also builds a common understanding and gives a background on how these concepts were translated into practice in research underpinning this body of public works and the theme of agricultural sustainability assessment. The subsequent paragraphs delves into the above issues.

1.2. The debate on agricultural sustainability and food production

1.2.1. Concept of Agricultural Sustainability

Agricultural production depends on the skilful manipulation of the ecosystem to provide products and services needed by humanity. In this Thesis, agriculture is understood in its broadest sense to include production of both crops and livestock. An agricultural system can be envisioned as an “ecosystem” (agricultural ecosystem = agroecosystem) with a biotic and biotic components, which interact (relate) as a unit, but the level and mode of interaction (ecological processes) has been modified through human influence for the production of food and fibre (Altieri, 1987)**.** Overtime, agricultural systems have been manipulated through improved technology and the use of diverse levels of inputs (fertilisers, irrigation, improved germplasm, labour etc.) to raise food production for increasing human populations. The production process where little or no inputs are used, for example in Sub Saharan Africa, and where excess inputs are used as in some Western countries has resulted in degradation of production resources (soils, water, biodiversity etc.) and a compromise on the ability of future generations to produce their own food in sufficient quantity and quality (Van Reuler and Prins, 1993; Lichtfouse, 2009; FAO, 2011). Thus, an understanding of the current agricultural systems’ sustainability and how they relate to meeting food needs of the present generation without compromising the ability of future generations to meet their own needs is seen as an important step in ensuring intergenerational equity, and agricultural sustainability (Tietenberg, 2003)

Certainly improved technology will assist in more effective management and use of production resources, but it cannot produce an unlimited flow of vital natural resources, which are the raw materials for sustained agricultural production. For instance, fertilizers enhance the fertility of eroded soils, but soil formation often proceeds at a painstakingly slow rate, sometimes beyond anthropogenic time scale. Today, global food production is sufficient to cater for every person on earth, yet 850 million people still go hungry, many of them are small scale farmers in developing countries (Angus, 2008). Although small scale farmers are increasingly modernising their farming systems, there are often, in more remote and marginal areas, many who are continuing with traditional farming practices under increasing population pressure. They can barely afford external inputs (improved germplasm, fertilisers, crop protection materials etc.), have limited opportunities for alternative livelihood sources, have inadequate access to resources and information, receive low returns on their labour (low yields and prices) and heavily rely on exploitation of natural resources to meet their daily needs. Thus, a different approach to agriculture is needed, one that can regenerate and conserve the land and other production resources, increase food production and address socio-economic and environmental issues (Reijntjes, Haverkort and Waters-Bayer, 1992; Pretty, 2008; Giovannucci et al., 2012).

Increasingly, researchers are showing that it is possible to provide a balanced environment, sustained yields, biologically mediated soil fertility and natural pest regulation through the design of diversified farming systems. Such diversified farming systems exploit the complementarities that result from the various combinations of crops, and animals in spatial and temporal arrangements in the landscape with the goal of striving for sustainable agricultural systems (Altieri and Nicholls, 2005). However, the development of sustainable agricultural systems in Kenya as well as other parts of sub-Saharan Africa (SSA) faces numerous challenges. Agriculture is no longer considered a purely technical option, but is viewed to be having an environmental dimension and an interaction with atmospheric system and hydrological cycles as well as with social, cultural, political and economic systems of the community where it is practised (Scholes, Dalal and Singer, 1994). The overarching issues in agriculture are now understood to transcend the classical boundaries of the biophysical sciences and have forced interaction with economics, sociology, anthropology and political science (Lampkin, 1990; Ashby, 1991; Nadia, 2000). Thus, there is need to have a deeper understanding of agricultural context given that agricultural development results from the complex interaction of a multitude of factors. The biophysical (environmental), socio-economic, institutional and policy factors that determine agricultural development need to be addressed simultaneously and in a holistic manner to make agriculture and food production sustainable (Altieri and Nicholls, 2005).

The concept of sustainable agriculture is a relatively recent response to the decline in the quality of the natural resource base associated with modern agriculture (Altieri and Nicholls, 2005). Agricultural sustainability embodies ecological, economic and social dimensions (Anon, 1995). Ecological dimensions include conservation of production resources (land, water, energy and biological resources), spatial and temporal relations; diversity, stability and resilience while economic facets of sustainability include resource distribution and allocation. The social dimension of sustainability addresses equity, access, stewardship and institutional arrangements. According to (Altieri, 1987) and (Ikerd, 1990), the above dimensions of sustainability must occur concurrently before agriculture can be considered sustainable. A farming system must be ecologically sustainable or it cannot persist over the long run, and thus cannot be productive and profitable. Likewise, a system must be productive and profitable over the long run, or it cannot be sustained economically no matter how ecologically sound it is (Altieri, 2012).

The concept of sustainability can be traced to environmental concerns that emerged in the 1950s-1960s and the renaissance of environmental and economic debates of 1960s-1970s on limits to growth (Pretty, 2008; Mebratu, 1998). However, it was not until the mid-1980s that the term became widely used in development circles, especially with the publication of the Brundland Report, Our Common Future, in 1987 that applied the terminology to development and gave the definition, "*Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs"* (WCED, 1987)

Applied to agriculture, *"a sustainable agricultural system is one that can indefinitely meet the requirements for food, feed, and fibre at socially acceptable economic and environmental costs"*, (Crosson, 1992). However, sustainability has defied a universal definition as (i) each scientific discipline contributes to the definition and (ii) each user group adds a different dimension to the concept and (iii) dimensions, in turn, are scale dependent that vary with time and space (Zinck and Farshad, 1995). Furthermore, sustainability is considered a “boundary term” where science meets politics and politics meets science and vice versa (Scoones, 2007). Others argue that sustainability is an activity that permanently satisfies a given set of conditions for an indefinite period of time (Hansen, 1996). Thus, it is no longer necessary to pause indefinitely for a universal definition so long as there are agreements on two conceptual points: (i) that sustainability is defined as an ethical guiding principle whose elements are derived from the current knowledge of science and (ii) that an innovative merger of the ecological, economic, and cultural contexts of sustainability are agreed upon as the mode of operation (Miller and Wali, 1995).

1.2.2. The drive towards agricultural sustainability in Sub-Saharan Africa

The countries in sub-Sahara (SSA) are characterised by agrarian economies with agriculture contributing to about 40% of exports, 30% of gross domestic product (GDP), 30% of foreign exchange earnings and 70-80% of employment (CFA, 2005). The agricultural sector is the major source of food supply and the dominant provider of raw materials for industries. The sector is dominated by smallholders who depend on it for economic activities and for food (Havnevik et al., 2007).

However, per capita food production in SSA has been on the decline since 1970s, in contrast to South America and Central America and the Caribbean (Figure 1.1). Although, it is estimated that demand for agricultural products in developing countries is expected to fall from an average 3.7% a year (over the past 30 years) to 2% a year (over the next 30 years, by 2030), partly as a result of China having passed the phase of rapid growth in its demand for food, food insecurity and poverty will still persist in some parts of developing countries (DCs), especially in SSA (FAO, 2002). This is because food production has lagged behind population growth and the DCs will have a projected annual cereal deficits of 14% (265 million tonnes of cereals) and 15% undernourished population (183 million) by 2030, and rising poverty from 240 million in 1990 to 345 million by 2015 (FAO, 2002).

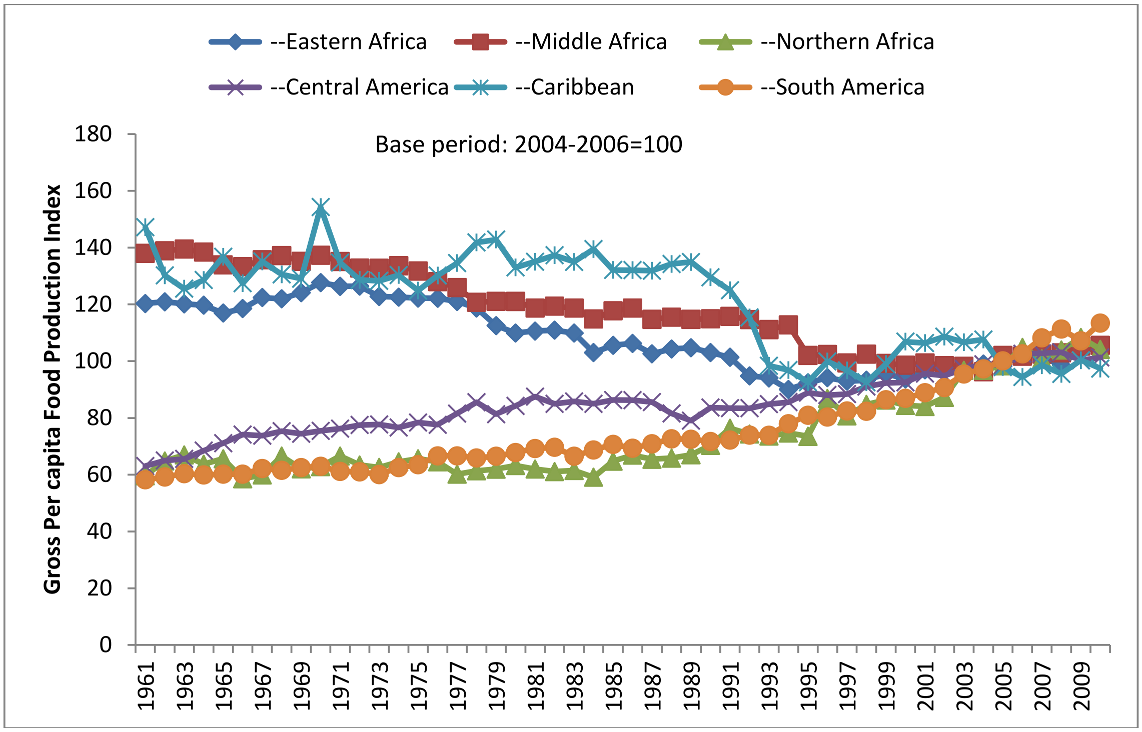


Figure 1.1: Regional trends in food production per capita (FAO, 2012)

It is estimated that more than 99% of the world's food supply comes from the land, and less than 1% are from the oceans and other aquatic habitats (Pimentel et al., 1995; Pimentel and Wilson, 2004). Therefore, the continued production of an adequate food supply is directly dependent on natural resources (soils, climate and water, energy and biological resources). Other factors influencing food supply include institutional and political factors (poor governance, inadequate physical infrastructure and market imperfections and weak public-private sector linkages) as well as socio-economic factors (HIV/AIDS, poverty, gender inequality) (Rosegrant et al., 2005). These factors, affecting agricultural productivity and therefore sustainability, are briefly described here-after:

Land

The availability of good quality land is an important determinant of food production in SSA. Studies indicate that the cultivated land in SSA is between 0.28 -0.52 hectares per person, but is decreasing with the increasing population (FAO, 2001a). For example, the per capita arable land in SSA declined from 0.53 to 0.35 hectares between 1970 and 2000 (FAOSTAT, 2002). It is estimated that human population in sub Saharan will rise from 901 million in 2012 to 2.2 billion by 2050 while the world population will arise from 7 billion to 10.6 billion over the same period (Nations, 2011). The rising population pressure in SSA is also expected to put pressure on arable land and diminish opportunities for agricultural extensification. Moreover, the arable land to be opened for cultivation, in the future in SSA, is expected to be marginal in nature and of low productivity. Thus, without massive technological improvements or substantial investments in agriculture, increases in food production in SSA and other low-income food-deficit countries will have to come from existing agricultural land through intensification (improving yields per unit land through improved farm technologies, Doos, 1994; FAO, 1995b).

As population pressure on land increases in SSA, disputes over the right to land has become common and without new land available, the existing land is being fragmented, especially under customary land tenure where children are bequeathed land from their parents. Furthermore, continuous cultivation on these land parcels with little or no nutrient replacements and conservation efforts is resulting in land degradation. Land degradation is the process by which the soils current or future capacity to produce is lowered by chemical, physical or biological changes. Global Assessment of Soil Degradation estimates that 65% of African agricultural land, 31% of permanent pastureland, and 19% of forest and woodland is degraded (Sivakumar and Wills, 1995). While there is general consensus that land degradation is taking place in SSA, there are conflicting perspectives on its extent and impacts on food production (Muchena, Onduru and De Jager, 2005).

Soils

Soils in Africa have various physical and chemical constraints that limit their production potential. Only 9 million km^2 of land or 29% of Africa has soils that could be classified as having little or no major constraints to agricultural production (Eswaran et al., 1997). The rest has various constraints, including low inherent fertility, nutrient deficiency, low organic matter, moisture stress and high erodibility. Shallow soils and soils full of gravel make up more than 27% (645 million hectares) of the soils of tropical Africa. These conditions result in poor infiltration and soil moisture retention. In these soils, moisture stress at critical periods in the life of the crops is common. The organic matter content of most soils in tropical Africa ranges from 10% (for soils derived from volcanic ash and basic amphibolites) to as low as 0.1% (very sandy soils) (Mokwunye, 2001). Reduced levels of organic matter result in poor stability of micro-aggregates making the soils more susceptible to erosion, surface sealing and reduced moisture-holding capacity. The Alfisols, Oxisols and Ultisols found in tropical Africa are characterized by the abundance of low-activity clays (primarily of the 1:1 lattice variety) and are thus prone to nutrient losses through leaching and erosion. It is also estimated that about 550 million hectares of land in Africa south of the Sahara and north of Limpopo suffer from acidity and the presence of free oxides of aluminium (Sanchez, Swift and Buol, 1991). These soils are known for their capacity to immobilize soluble phosphorus (P fixation).

Water

Water is critical for crop production and about 70-87% of the world's fresh water is consumed or used in agriculture (Shiklomanov, 1998; Pimentel and Wilson, 2004; Pimentel *et al*., 2004). In 1997-1999, irrigated land represented about 20% of total arable land area in developing countries, but accounted for 40% of total crop production and 60% of cereal production (FAO, 2002). The demand for irrigation water is, however, expected to rise in the future. It is projected that developing countries will have a 14% increase in water withdrawals for irrigation by 2030 (FAO, 2002). Although the potential for irrigation in SSA has not been exhausted, irrigation costs in SSA are higher than in Asia and often generates low benefits due to (i) inherently difficult agroclimatic and agronomic conditions, (ii) low use of improved crop varieties and complementary inputs, (iii) labour scarcity, (iv) insecure land tenure, (v) problems in coordinating technical and socioeconomic aspects of irrigation (vi) poor operation and maintenance, and (vii) overvalued exchange rates, which is a disincentive to agricultural production (Rosegrant and Perez, 1997).

Climate

Sudden catastrophic events associated with climate change have been partly responsible for low agricultural production in SSA. Droughts (e.g. in Ethiopia, Sahelian countries) and floods (e.g. Southern Africa, Mozambique) are a fundamental part of the climate in SSA. In the period 1975-2002, disasters of hydro-meteorological origin constituted 59% of the total natural disasters in sub-Saharan Africa with floods accounting for 27%, drought for 21%, windstorms (particularly tropical cyclones) for 9%, and wildfire accounting for 1% (ICSU, 2006). The United Nations Office for the Coordination of Humanitarian Affairs recently reported that over 10 million people were on the brink of starvation in the Horn of Africa (Kenya, Djibouti, Ethiopia, Eritrea and Somalia) due to severe drought, crop failure and loss of livestock (Actalliance, 2011). Since 1993, 7 national disasters have been declared in Kenya five of which have been drought related with 2008-09 drought culminating in appeals for food aid internationally (Huho and Mugalavai, 2013). Up to the year 2030, the greatest impacts of climate change in SSA are expected to come from increased frequency and intensity of extreme weather events. Also by 2030, climate change is projected to depress cereal production in Africa by 2 to 3 percent (FAO, 2002).

Energy

Fossil energy is another prime resource used for food production. Nearly 80% of the world's fossil energy is used annually in the developed countries and the developing countries have to pay dearly for such energy sources in the form of fertilizers and irrigation and fuel for farm machinery and transportation (Pimentel and Pimentel, 1996; Pimentel and Wilson, 2004). Studies have shown that African farmers pay the highest price for fertilisers around the world (Camara and Heinemann, 2006). The SSA region consumes 2.7% of world commercial primary energy and has the lowest commercial energy use as reflected in the low level of economic activities in the region (Sokona, 1997).

Biological resources

Another dimension to improved agricultural productivity and food production is the biodiversity conservation. Diverse species of organisms are natural enemies of pests and they degrade wastes, form soil, fix nitrogen, pollinate crops and provide opportunities for risk aversion in agriculture among other roles (Hinrichsen and Robey, 2000). Over 40,000 species of plants, animals, fungi, and microbes are regularly exploited for human benefit and about 600,000 species are estimated to have vanished since 1950 (Eldredge, 1998; Myers, n.d.).

Development, dissemination and adoption of new technology

The development and dissemination of new technology is an important factor determining the future of agriculture. Sub-Saharan Africa has the lowest public expenditures on agricultural research (lower than global average ratio of public spending to GDP of 1.04[40]). Public agricultural research expenditure in SSA grew at 1.5% annually in the period 1976-1996, a growth which was only one-third the rate of developing countries as a whole (Pardey and Beintema, 2001). Similarly, the percentage of public research expenditure as a share of Gross Domestic Product (GDP) in SSA declined in the period 1976-1995, in contrast to other developing and

[40] Investing in Sub-Saharan Africa Agricultural Research: Recent trends: International Food Policy Research Institute 2020 Africa Conference Brief No.8, 2004.

the developed countries where there was an increase in the same period. Also, the dwindling public funding of research in SSA has not been matched with increasing private sector funding, which is estimated to be only 2% of total agricultural research funding. In the year 2000, private spending on agricultural research in East African countries amounted to 1.6% of total research costs (Beintema and Stads, 2004). However, agricultural research funding is increasingly becoming scarce, erratic and donor dependent. In addition to low investments in agricultural research, the dissemination and adoption of agricultural technologies in SSA has also been slow (Malton et al., 1984).

Institutional and political factors

Among the political and institutional factors, poor governance in some of the SSA countries has contributed to declining agricultural productivity and food security. Corruption, collusion and nepotism and other governance problems are often correlated with conflict and linked to hunger and food insecurity, both as a cause and as an effect (Estache and Kouassi, 2002; Messer and Cohen, 2004). Under such conditions the political and legal frameworks that enable successful agricultural development through strong institutions, sound infrastructure (input and output markets, roads, electricity, telephone etc.), community participation and empowerment, social equity and justice, and government accountability are inadequate or lacking. Recent examples can be found in Somalia and Zimbabwe.

Socio-economic factors

Among the daunting socio-economic factors that have slowed down the pace of agricultural production in SSA are HIV/AIDS and poverty. While HIV/AIDS strikes the most productive age group and lowers labour potential for agriculture, the HIV/AIDS infected individuals also require up to 50% more protein and 15% more calories than the rest of the population (Haddad and Gillespie, 2001).

In 2011, the 23.5 million people living with HIV/AIDS in SSA represented 69% of the total world population living with HIV/AIDS (UNAIDS, 2011.) In the same period, 1.6 million people were living with HIV/AIDS in Kenya and 1.2 million people died of HIV/AIDS in SSA, representing 71% of total world AIDS deaths. Memfih (2005) has underscored the impacts of HIV/AIDS on agriculture to include (i) absenteeism from work and loss of labour (ii) reduction in area under cultivation (iii) reduction in yields (iv) reduced food production and food insecurity (v) declines in crop diversity and thus quality of diet; and changing cropping patterns (vi) adoption of less labour intensive farming practices and a shift away from labour-intensive crops (vii) delayed farm operations (viii) loss of knowledge about traditional farming methods (ix) loss of assets (x) loss of remittances in areas where agricultural workers send money home while working abroad; and (xi) erosion of traditional coping mechanisms (traditionally, local residents always joined together to offer assistance to those in need).

Besides HIV/AIDS, poverty also has adverse effects on agriculture and food production, as many farmers in SSA cannot afford to purchase inputs such as inorganic fertilisers, crop protection materials and improved seeds. In 2002, SSA's share of population in poverty fell to 44 percent, below the 46.4% in 2001 but virtually the same as in 1990. In 2008, poverty in SSA stood at 48% with one third of the World's poor estimated to be living in SSA (World-Bank, 2012). Population falling below poverty line in Kenya is estimated at 45%[41]. According to (WorldBank-FAO, 1996), the nexus of low productive agriculture and poor soil resource base in SSA, attributed to inadequate use of inputs, and growing population create synergies that exacerbate existing degraded soil resource base, thus creating a vicious circle of poverty, food insecurity and unsustainable farming practices.

1.2.3. Smallholders and competing views on agricultural sustainability and food production

Smallholder agriculture dominate developing countries with Asian countries having a high percentage of small farms followed by Africa while Latin America has the lowest percentage of small farms under two hectares (Zhou, 2010). Improving productivity and the sustainability of smallholder farms is a priority for reducing hunger and poverty and reversing declining quality of natural resources on which agriculture depends. While the definition of smallholders vary according to context, land size and enterprises considered, the following features are usually associated with smallholders as defined by Ethical Trading Initiative (ETI) Smallholder Guidelines (ETI, 2005):

- They produce relatively small volumes of produce on relatively small plots of land; have low productivity.
- They may produce an export commodity as a main livelihood activity or as part of a portfolio of livelihood activities.
- They are generally less well-resourced than commercial-scale farmers.
- They are usually considered to be part of the informal economy (i.e. may not be registered, tend to be excluded from aspects of labour legislation, lack social protection and have limited records).
- They may be men or women.
- They may depend on family labour, but may hire workers.
- They are often vulnerable in supply chains.

In sub-Saharan Africa, smallholder production is largely at subsistence level. The smallholders have limitations in increasing agricultural productivity, which includes the following among others: limited access to credit and ability to invest in improved inputs (seeds, crop protection materials, irrigation etc.) and soil fertility replenishment strategies; about 80% of them live in areas where rainfall is low and erratic and soils tend to be infertile; face high post-harvest losses; receive little technical support and have poor research-extension linkages; have low and unattractive prices for their produce; and have been slow to adapt to changing environments and new technologies (Muzari, Gatsi and Muvhunzi, 2012). The stallholders rely on labour-intensive production methods and it is estimated that 80% of the staple food in Africa is grown by women who also account for 70% of agricultural labour (IAASTD, 2009).

Opinions stand divided on the best way to improve on agricultural productivity and sustainability of smallholder farms. About five proposals are in the public arena being debated with none being treated solely as the panacea pathway towards improving productivity and sustainability (Pretty, 1998): (i) limit to growth-this view subscribes to the fact that ecological limits are being approached or have been reached. It is only

[41] Poverty line used by “Exploring Kenya Inequality: pulling apart or pulling together” study was Ksh 2,913 per month-Kenya National Bureau of Statistics and Society for International Development (SID) report, November 2013.

population control that can prevent Malthusian type of crisis instead of advancements in technology (Malthus, 1798); (ii) Business-as-usual optimists-believe that market forces will ensure steady supply of food products as new technologies get adopted, and food prices fall and population decreases; (iii) Redistribution of food from industrial to developing counties-this view believes that developing countries will never be food self-sufficient, are un-mechanised smallholders and soon marginal farmers will be put out of business. It is the industrial countries that will supply food to the developing world; (iv) Creating a Green Revolution for Africa-advances the view that smallholders in Africa use limited inputs and high external input farming would be the way to go[42]; and (v) Intensification view-believe that it is possible to produce more food from the same land parcel while conserving the environment by using intermediate or low-external input strategies. However, proposals (i) to (iv) have been challenged over time. Human innovations, ingenuity and technological advancement have challenged the theory of limits to growth, market forces have failed to ensure equity in distribution of food between the developed and developing countries and green revolution has not been attained in Africa due to socio-economic environment and policy factors. Attempts are being made at agricultural intensification in Africa: increasing yields per hectare, increasing cropping intensity per unit of land or inputs; and promotion of high market-value crops, though constrains still abound such as high poverty, insufficient purchasing power to access agricultural inputs and lack of conducive policy environment (Foresight, 2011).

42 Carol B.Thompson: How healthy for Africans is the Alliance for a Green Revolution for Africa? available at: http://www.seattleglobaljustice.org/wp-content/uploads/how-healthy-for-africans-is-the-alliance-for-a-green-revolution-for-africa-agra1.pdf

Appendix 2: Examples of Participatory Tools used for Joint Learning on Smallholder Agricultural Sustainability

Figure 2.1: Example of farmers' soil map

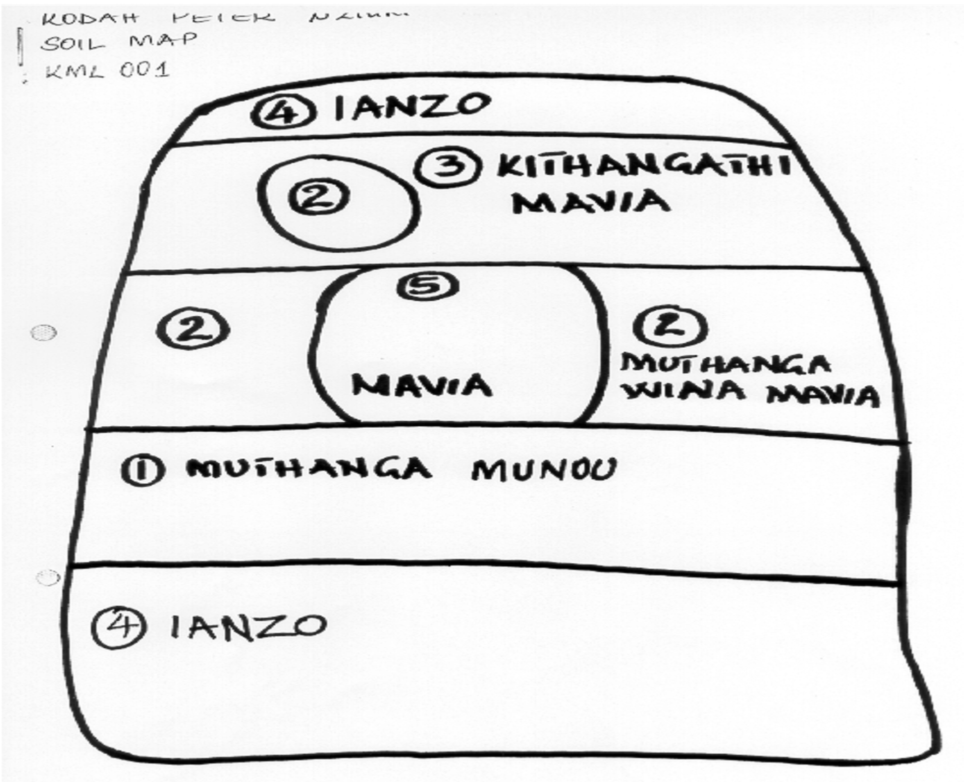


Figure 2.2: Example of Soil Sample Feedback Report

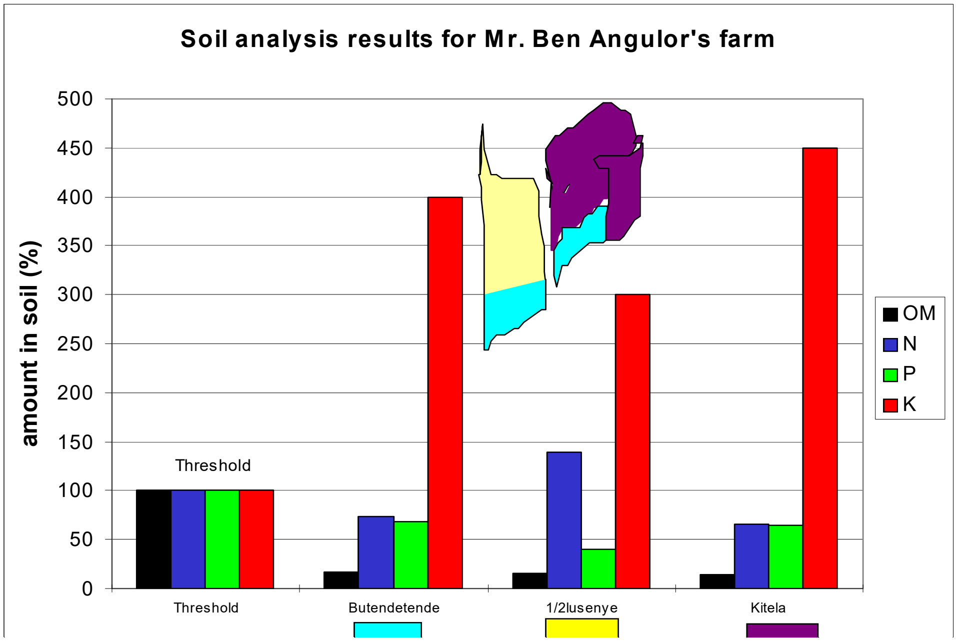
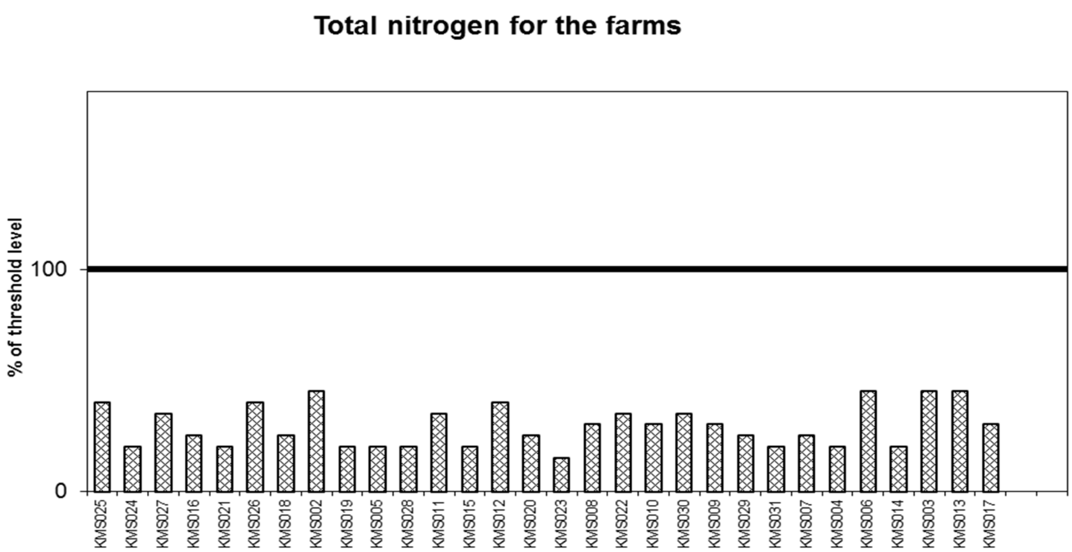


Figure 2.3: Example of



Soil Sample Feedback Report (used in 2001-2005)

Figure 2.4: Example of Soil Sample Feedback Report (used in 2006-2012)

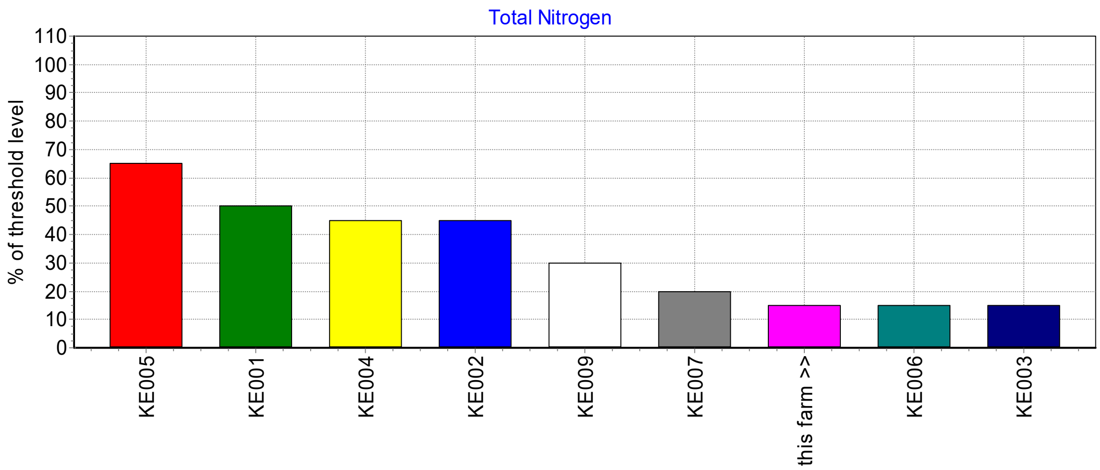


Figure 2.5: Example of resource and nutrient flow maps

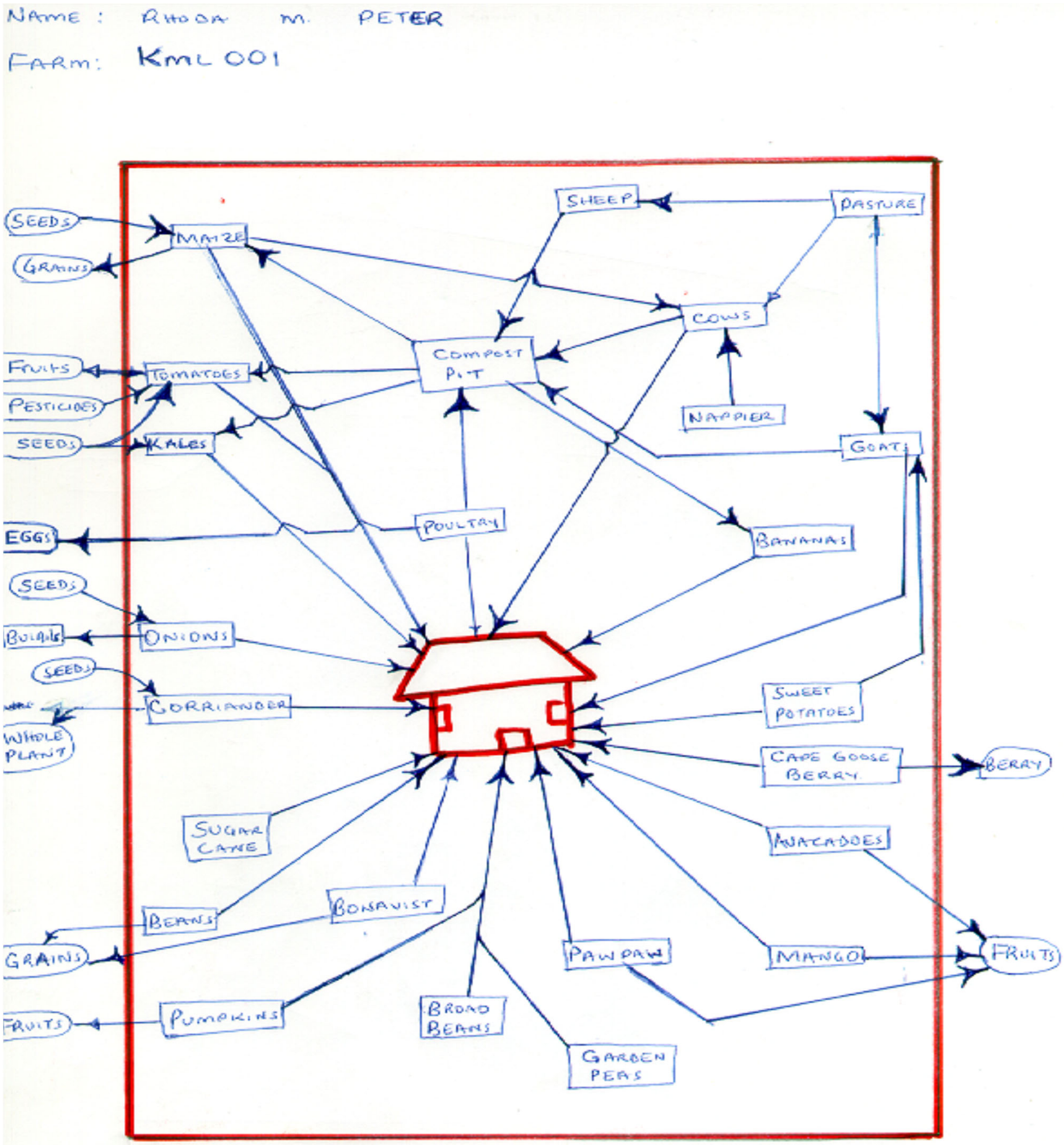


Figure 2.6: Example of farmers individual feedback sheet-nutrient balance

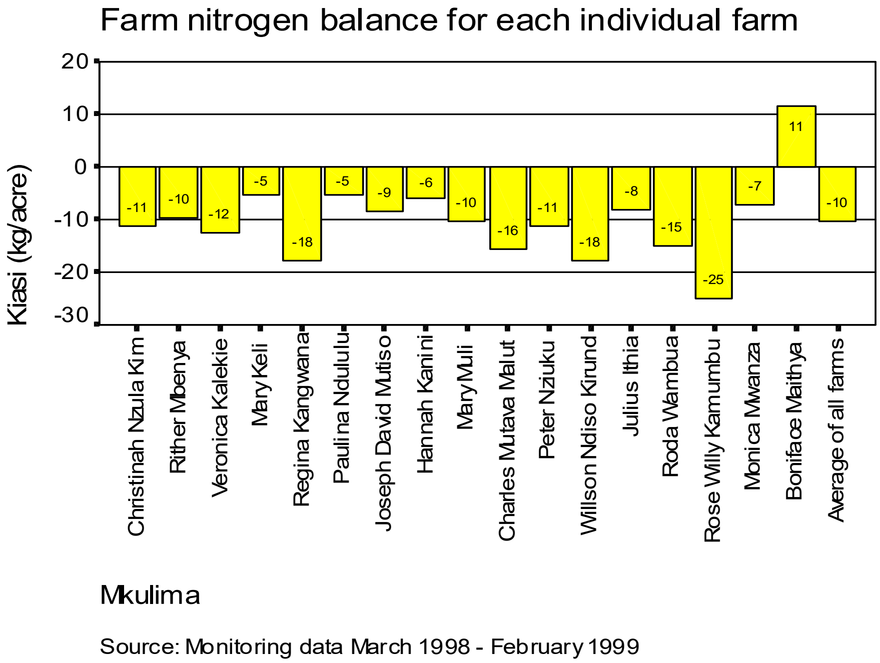


Figure 2.7: Example of farmer's individual feedback sheet-farm labour use (Year 2009)

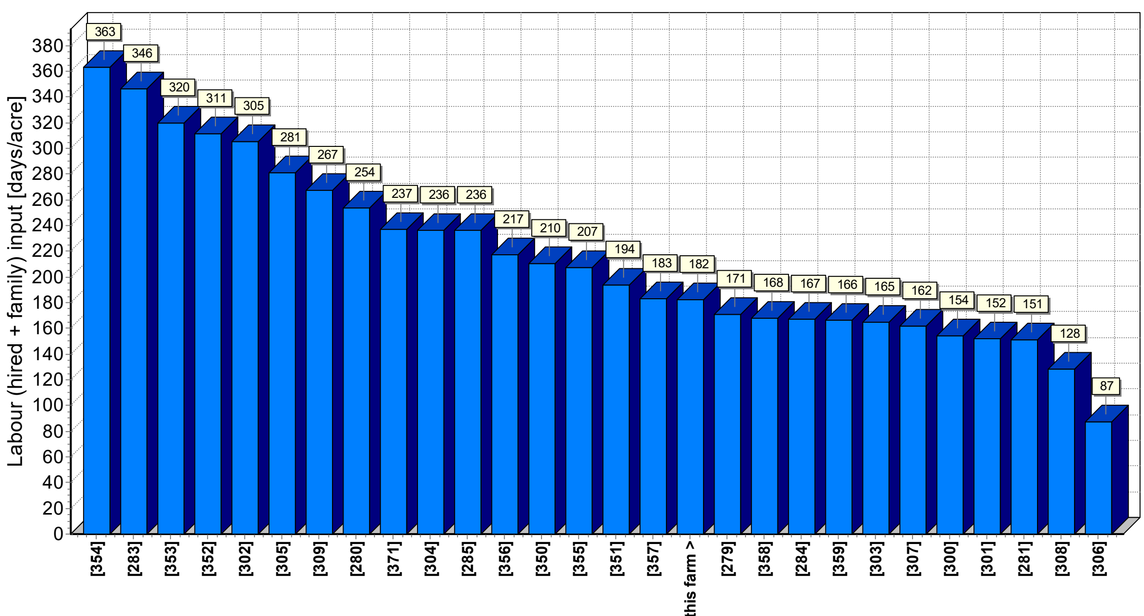


Figure 2.8: Example of farmers' individual feedback sheet-tea yields (Year 2009)

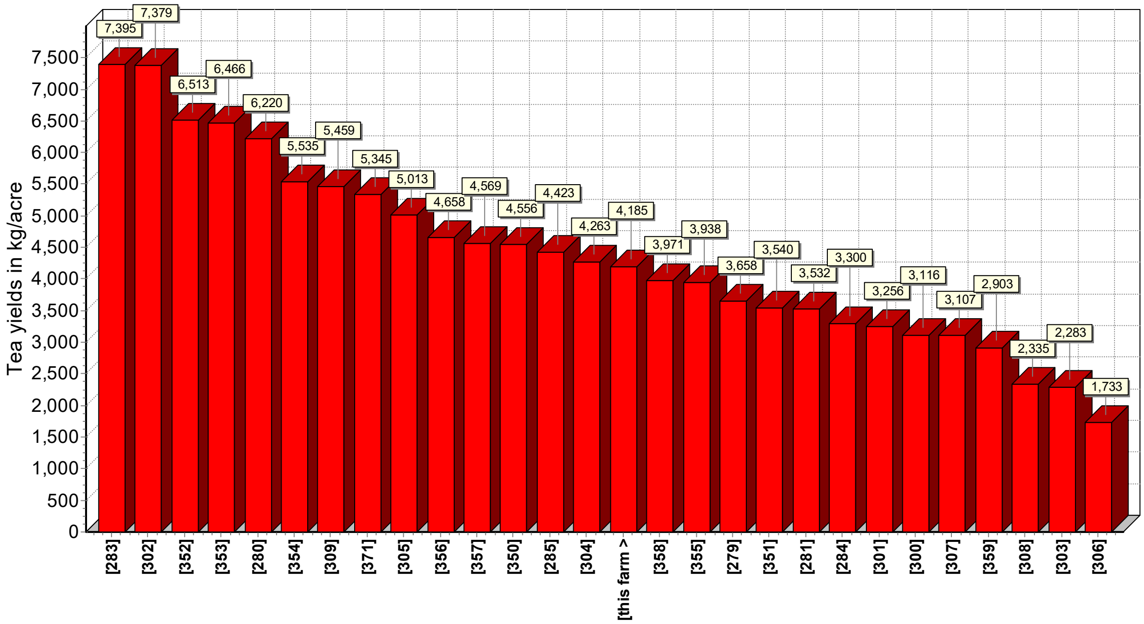


Figure 2.9: Example of farmers individual feedback sheet-Net farm income (1997-200)

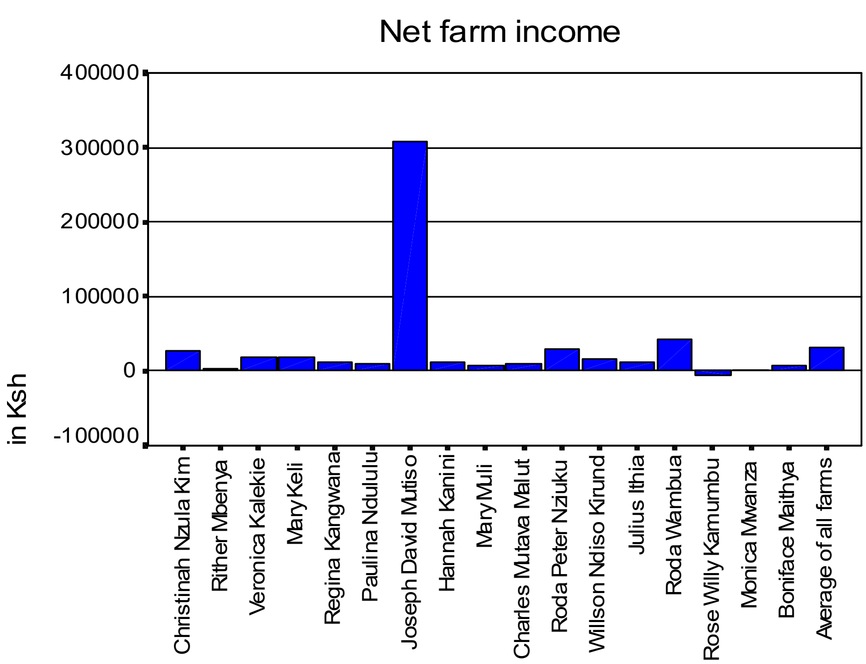


Figure 2.10: Example of farmers' individual feedback sheet-Net Cash Flow (2009)

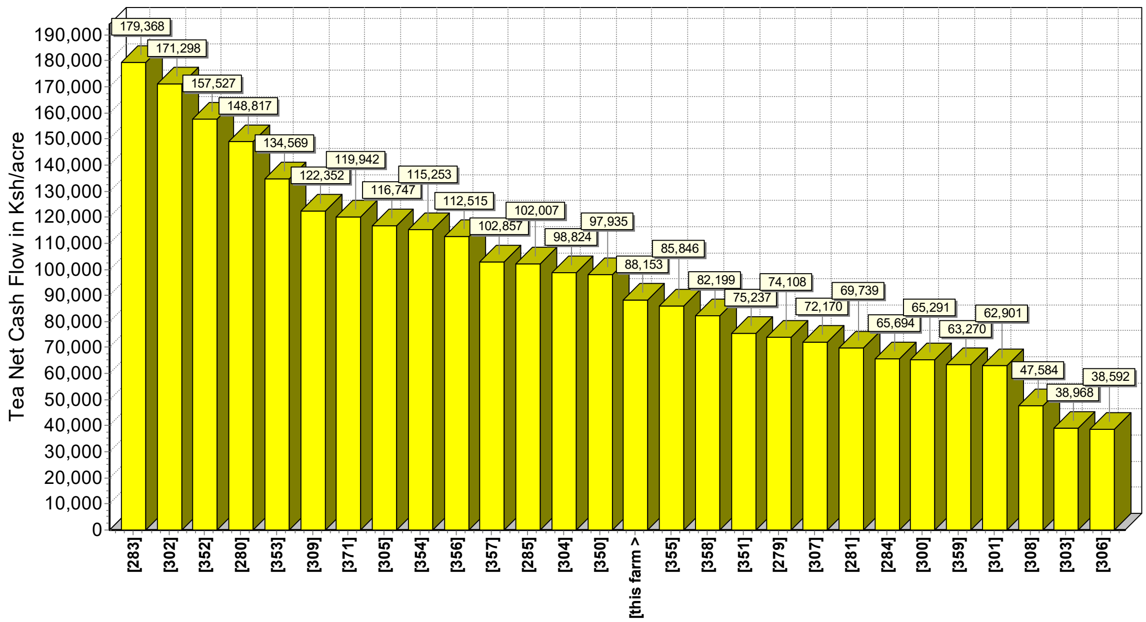


Figure 2.11: Example of participatory Technology Development planning map

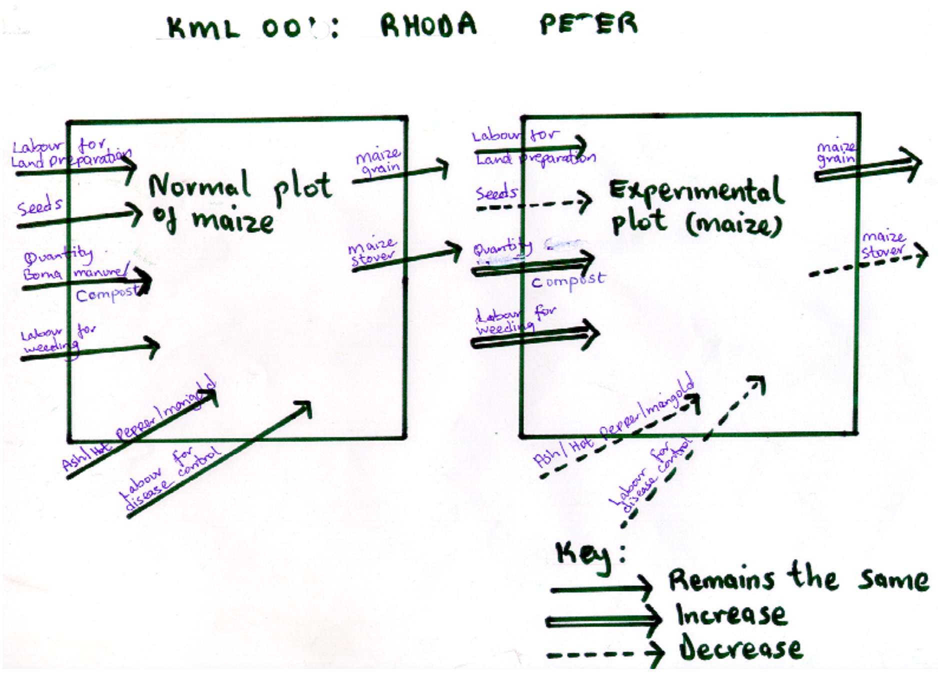


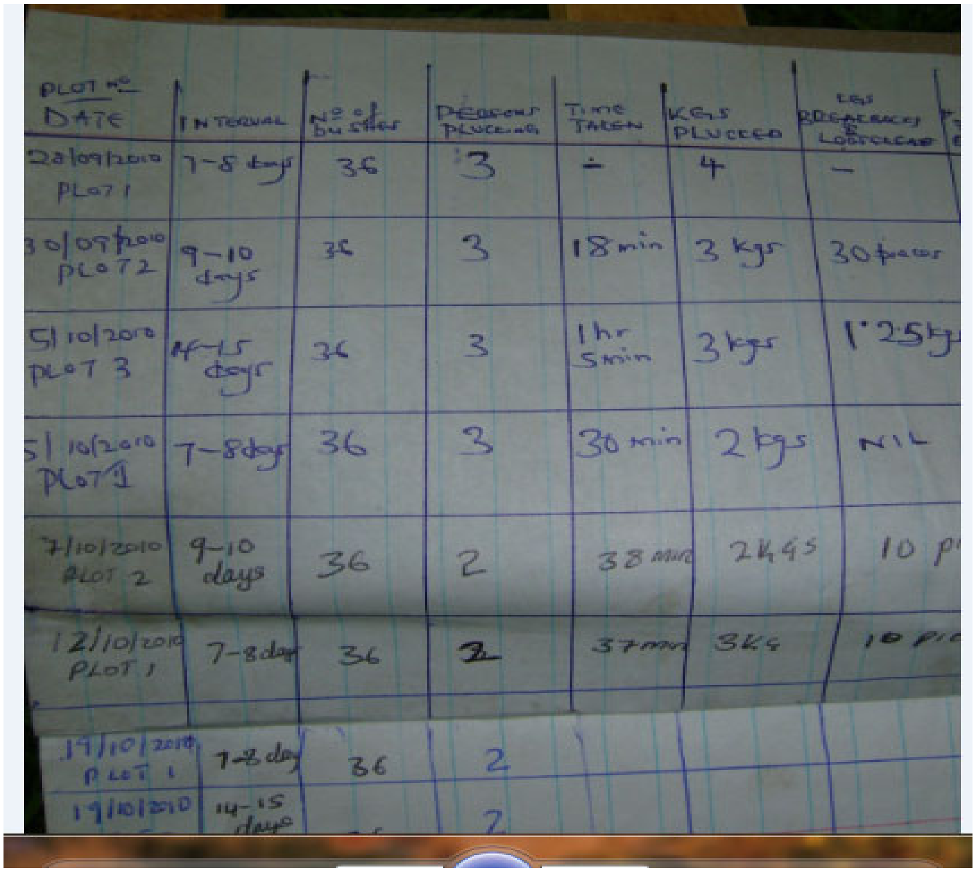
Figure 2.12: Example of farm labour record sheet (use of stones)

Activity	Treatment 1	Treatment 2
Planting	○○○○	○○○○○
Weeding	○○○○○	○○
Manure application	○○	○○○○○○

○ - stone representing one labour unit, e.g. hour, day

Figure 2.13: Example of Farmer Field School learning trial/PTD plots on tea management
Source: Davies Onduru

Figure 2.14: Farmer Field School Participant explaining how learning takes place in FFS learning trial plots (PTD activities): Source-Davies Onduru



PLOT No / DATE	INTERVAL	No of bushes	Persons plucking	Time taken	KGs plucked	KGs Breakbacks & Loose leaf
28/09/2010 PLOT 1	7-8 days	36	3	-	4	-
30/09/2010 PLOT 2	9-10 days	36	3	18 min	3 kgs	30 pieces
5/10/2010 PLOT 3	14-15 days	36	3	1 hr 5 min	3 kgs	1.25 kgs
5/10/2010 PLOT 1	7-8 days	36	3	30 min	2 kgs	NIL
7/10/2010 PLOT 2	9-10 days	36	2	38 min	2 KGS	10 p
12/10/2010 PLOT 1	7-8 days	36	2	37 min	3 KGS	10 pie
19/10/2010 PLOT 1	7-8 days	36	2			
19/10/2010	14-15 days		2			

Figure 2.15: Example of records of observations made by farmers on PTD plots

Appendix 3: My Reflections on Research Paradigms and Methods

I subscribe to the belief that no paradigm is the "most correct" as each researcher bases research in some paradigm intentionally or in "unspoken manner". Each researcher has a belief system about the world and how to interact with that world which in turn influences decisions made on how to conduct research and what counts as valid knowledge. The formal *expose'* of this belief system, referred to as research paradigm, can be traced to the work of Kuhn's 1970 book "The Structure of Scientific Revolutions" (Kuhn, 1970). In literature, however, the research paradigm (or belief system) has been given four meanings "(1) Worldviews, an all-encompassing perspective on the world; (2) epistemologies, incorporating ideas from the philosophy of science such as ontology, methodology, and epistemology; (3) "best" or "typical" solutions to problems; and (4) shared beliefs of a "community of scholars" in a research field" (Creswell, 2011). The fourth meaning is quite often emphasised in literature with paradigms being understood as sets of research beliefs and practices established and shared by community of researchers, which regulate how research is conducted in a given discipline (Creswell, 2011; Weaver & Olson, 2006; Morgan, 2007). The second definition is commonly used in social sciences where a paradigm is defined as an epistemological stance (Hal, 2012) while other writers in the field have adopted the first definition where a paradigm is understood as a world view with its elements being referred to as philosophical assumptions on which researchers adopt stances separately (Cresswell & Plano Clark, 2007; Greene, 2007; Teddlie & Tashakkori, 2009). Nevertheless, the philosophical underpinnings of a paradigm can neither be proven nor disapproved since they are human constructs categorized by differences in belief and value systems (Guba, 1990; Hamilton, 1994).

Each paradigm can be considered a meta-theory and has distinct components or paradigmatic elements which include philosophical claims or assumptions on what is considered to be existing and constitutes reality in the world and therefore *knowable* or what can be known in the world (ontology), how knowledge about that reality can be created, acquired and justified and what its nature/essence is (epistemology), strategy or plan of action explaining the choice of particular methods to gain the knowledge including why, what, from where, when and how data is collected and analysed (methodology), specific techniques and procedures used to collect and analyse data (methods), the values we have about that knowledge (axiology) and how we can write about that knowledge (rhetoric).

In my reflections on personal research journey, I reviewed and reflected on the current research paradigms and on how they influenced my research on agricultural sustainability. While on this journey of personal discovery, I realized that most of the current paradigms, as a standalone, only contribute partly to understanding my personal epistemology. I hereby review these paradigms and why I felt they were inadequate in underpinning my research work as a whole before turning to describe my epistemological stand on pragmatism as a world view that has informed my research practice and research design (for pragmatism see Chapter 4).

Positivism (postpostivism, logical positivism)

Ontological commitment of positivism is realism where objects or phenomenon to be studied is believed to exist independent of the researcher and thus the reality which is "knowable" exist independent of the researcher, driven by immutable laws, cannot be mediated by human senses and is not value laden (Scotland, 2012). Epistemological assumption of the paradigm is that of objectivism where the researcher is not part of the context in which the knowledge is generated and meaning is seen to reside in the objects/phenomenon and not in the conscience of the researcher. Thus the discoverable knowledge is value-free and is not situated in the political and historical context (Pring, 2000; Cohen *et al*., 2007). This paradigm underpins the "scientific paradigm" and is meant to explain relationships, identify causes which influence outcomes and formulate universal laws that can be used for prediction and generalization (Creswell, 2009). Knowledge is arrived at through deductive processes and analysis involving descriptive and inferential statistics based on quantitative data. The ultimate aim is to discover, predict and control natural phenomena.

This paradigm has partly played a part in informing my research decisions on all the four sub-themes outlined in Chapter 1 of this context statement, but cannot underpin all the various components of my research which require "rich context" in addition to the *positivist science* for full interpretation. In this paradigm I'm not able to understand myself as the *perceiver* of my world or as *constructor* of my world (Ashworth, 2003) which then limits my potential to position all my public works.

Constructivism (interpretivism)

The ontological stand of constructivism is relativism that views reality as subjective and differs from person to person. Reality is individually and socially constructed based on experience and context and so there are multiple realities i.e. people construct meaning in different ways even when looking at the same thing. The constructivism epistemology is one of subjectivism based on real world and co-creation of knowledge. Knowledge is constructed out of the interaction between humans and their world and is developed and disseminated in a social context including historical and cultural context in which people inhabit (Creswell, 2009). Constructivism is associated with the view of phenomenology which refers to the study of direct lived experience and the way people make sense of their world through creating meanings from experience (Saunders *et al*., 2007). Research under this paradigm is justified when it can provide rich evidence and credible information (internal validity/credibility), can be used by someone else in a different situation (external validity/transferability) and the research process and findings can be replicated (reliability/dependability) (Scotland, 2012). However, the fact that constructivists tend to believe that time-and context free generalizations are not desirable likely renders inappropriate the use of inferential statistics to make generalizations across populations.

Constructivism partly underpins my thinking with regards to the various publications presented with this context statement, but particularly so for publications 9, 10, 11 and 12 touching on farmer field schools as a learning approach. However, farmer field schools were used as one component of a larger study process which also included components that were partly informed by positivism and transformative-emancipatory paradigms.

Transformative-emancipatory paradigm

The transformative-emancipatory paradigm has ontological commitment which is value laden and moral in nature and sees objectivity as impossible with the belief that multiple realities exist, is contextual, relational and historically constructed (Hal, 2012). It further states that local people have the potential for local agency, when their conscience is raised, to change existing power structures resulting from historical imbalances and to take action to better their lives (Gaventa & Cornwall, 2001; McIntyre, 2002). Epistemological assumption is that knowledge creation is an active process where researchers and participants collaborate to jointly create and shape knowledge based on local political and socio-economic contexts by participating in all phases of research and taking action and control over their situation. Furthermore since solutions to problems are negotiated among stakeholders, knowledge is uncertain, evolving, and contextual and value laden (McNiff & Whitehead, 2006). In addition this paradigm has special emphasis on marginalized groups (women, ethnic minorities, gay and lesbians etc.) and those who are poor (Mertens, 2003).

This paradigm has played part in underpinning my research work on participatory technology development (PTD) with the same epistemological assumptions (publications 9, 10, 12 and 13). However, I have used PTD as part of a larger body of research process that also includes components of other research activities that have been anchored in philosophical assumptions of other paradigms. Thus, this paradigm is inadequate as a single paradigm underpinning my research work.

Research methodology and methods used

A summary of my research methodology and research methods are is given in Table 3.1. and described by research Project and by publication/body of works.

Table 3.1: Methodologies and methods used in public works (1993-2012)

Publication No.	Approach	Methodology	Methods
INMASP Project			
1	Quantitative	• Household and farm survey	• Soil sampling and laboratory analysis • Literature review • Semi-structured interviews • Descriptive data analysis (Factor analysis) • Absolute assessment of sustainability
2	Quantitative	• Household and farm survey • QUEFTS methodology	• Semi-structured interviews • Literature review • Soil sampling and laboratory analysis • Literature review • Historical analysis of crop yields • Time series-data analysis • Descriptive analysis • QUEFTS model output analysis • Absolute assessment of sustainability
3 and 4	Quantitative	• NUTMON methodology • Household and farm survey	• Semi-structured interviews • Literature reviews; secondary data reviews • Descriptive analysis • Correlation analysis • NUTMON model output analysis; nutrient balance analysis • Absolute assessment of sustainability
9.	Quantitative + Qualitative	• Farmer Field Schools • Participatory Technology Development • Household and farm survey • NUTMON methodology	• Literature review • Participant observation • Group assessment • Soil sampling and laboratory analysis • Photographs of nutrient deficiencies • Video capture and participatory analysis • Group assessment and evaluations; group interviews • PTD trial joint analysis with farmers • Agro-ecosystem analysis • NUTMON model output analysis; Nutrient balance analysis • Semi-structured interviews • Descriptive statistical analysis • Absolute + comparative sustainability assessment
10	Quantitative + Qualitative	• Farmer Field Schools • Participatory Technology Development • Household and farm survey • NUTMON methodology	• Literature review • Participant observation • Group assessment and evaluations • Soil sampling and laboratory analysis • Photographs of nutrient deficiencies • Video and participatory analysis • Group assessment and evaluations; group interviews • PTD trial joint analysis with farmers • NUTMON model output analysis • Agro-ecosystem analysis • Semi-structured interviews • Descriptive statistical analysis • Absolute + comparative sustainability assessment

Publicatio n No.	Approach	Methodology	Methods
13	Quantitative + Qualitative	• Household and farm survey • Participatory Rural Appraisal	• Literature review • Semi-structured interviews to capture perceptions • Scoring and ranking • Historical trend analysis • Descriptive statistical analysis • Inferential statistical analysis • Absolute + comparative sustainability assessment
15	Qualitative + Quantitative	• Causal linkage reviews and case studies • Literature survey	• Literature reviews • Historical trend analysis • Expert interviews; Key informant interviews • Absolute + comparative sustainability assessment
Sustainable tea project			
11	Quantitative + Qualitative	• Farmer Field Schools • MonQI methodology • Participatory Technology Development • Integrated sustainability assessment framework	• Literature review • Semi-structured interviews • PTD trials joint analysis with farmers • Agro-ecosystem analysis • Group assessment • Sustainability score index • Group assessment and evaluations; group interviews • Absolute + comparative sustainability assessment
OFEA Project			
6	Qualitative	Comparative farming system assessment	• Reflection on experiences with research methodology • Literature review • Comparative system sustainability assessment
7	Quantitative +Qualitative	• Participatory on-farm research • Farmer evaluations • Comparative farming system assessment	• Participatory trial joint analysis with farmers • Literature review • Evaluation and reflection in group meetings • Field days • Semi-structured interviews to capture impact • Nutrient balance analysis • Comparative system sustainability assessment
LEINUTS			
8	Quantitative + Qualitative	• Comparative farming system approach • NUTMON methodology • Participatory Rural Appraisal	• Semi-structured interviews • Literature reviews • Soil sampling and laboratory analysis • PRA methods: Resource flow mapping tools; soil mapping; visual charts • Descriptive statistical analysis • Group analysis • NUTMON model output analysis • Comparative system sustainability assessment
12	Quantitative + Qualitative	• Survey • NUTMON methodology	• Participatory soil characterization • Soil sampling and laboratory analysis • PTD trial joint analysis with farmers • Descriptive analysis

Publicatio n No.	Approach	Methodology	Methods
		• Participatory Technology Development • Policy dialogue and scenario development	• Group analysis • Stakeholder and local policy workshops • Absolute + comparative sustainability assessment
14	Quantitative + Qualitative	• Survey • Participatory soil characterization	• Inventory of farmers' indigenous technical knowledge on soils • Soil sampling and laboratory determinations • PRA methods and tools: soil mapping • Absolute + comparative sustainability assessment
GWC			
5	Quantitative + Qualitative	Survey	• Semi-structured interviews • Expert interviews; key informant interviews • Absolute assessment of sustainability

Appendix 4: My research collaboration and productivity

4.1. Introduction

Opinions are divided on what constitutes research collaboration as collaboration can occur at different levels: between individuals, groups, departments, institutions, sectors and countries. In this body of works I have adopted the definition of the major form of collaboration transcending this body of works, aligning it with the definition given by Mattessich *et al*. (2001), "A mutually beneficial and well-defined relationship entered into by two or more organizations. The relationship includes a commitment to mutual relationships and goals; a jointly developed structure and shared responsibility; mutual authority and accountability for success; and sharing of resources and rewards". I have similarly adopted the definition of the Committee on Facilitating Interdisciplinary Research, National Academy of Sciences, National Academy of Engineering and Institute of Medicine (2004) regarding interdisciplinary research, "…..a mode of research by teams or individuals that integrates information, data, techniques, tools, perspectives, concepts, and/or theories from two or more disciplines or bodies of specialized knowledge to advance fundamental understanding or to solve problems whose solutions are beyond the scope of a single discipline or area of research practice".

In this section, I describe the nature of my research partnerships, how they were formed and their productivity. I have used co-authorship network and metrics to underscore the latter.

4.2. Motivation to form Research Partnerships

I begin this Section by looking at collaborations and partnerships within which this body of works was produced. According to Horton *et al*. (2009) partnership arrangements include research consortia, networks, alliances and partnership programmes. The partnerships within which this body of works was produced can be described as research consortia implementing collaborative interdisciplinary research except for NUTNET and "Enhancing soil fertility in Africa: from field to policy maker", which were Networks (Table 4.1). Donors who sponsored the various research projects are considered development partners in this framework.

Table 4.1: Collaboration and Partnerships

Research Project	No. of Partner organisations	Types of Partners	Geographical scope	Research focus
OFEA (1994-1998)	2+ A donor and farmers	Local NGO; International Development Organization; Donors; Farmers	Kenya, Uganda, Tanzania; European partner from Netherlands	Research on potentials and limitations of organic farming; Adoption of organic farming practices
LEINUTS (1997-1999)	7 + A donor and farmers	Local NGOs, National Research Institutions, Universities; Donors; farmers	Kenya, Uganda, European Partner from Netherlands and Portugal	Research on low external inputs agriculture and sustainable agriculture; organic farming
Networking on soil fertility management: Improving soil fertility in Africa-Nutrient networks and stakeholder perceptions (NUTNET) Dec 1997-1999	15+ Donor	NGOs; Agricultural Research Organisations; Universities	Six African Countries: Kenya, Uganda, Ethiopia, Zimbabwe, Burkina Faso and Mali Two European Countries: UK, Netherlands	Networking and information sharing among researchers and organisations working on soil fertility management in Africa and their European Counterparts

Research Project	No. of Partner organisations	Types of Partners	Geographical scope	Research focus
Enhancing soil fertility in Africa: from field to policy maker 1998-2001	19+ Donor	NGOs; Agricultural Research Organisations; Universities	Six African Countries: Kenya, Uganda, Ethiopia, Zimbabwe, Burkina Faso and Mali Five European Countries: UK, Netherlands; Sweden; Spain; Greece	Continued with the work of NUTNET on soil fertility management; and policies on soil fertility
INMASP 2001-2005	9 + A donor and farmers	Local NGO, National Research Institutions, Universities; Donors; farmers	Kenya, Uganda and Ethiopia, European Partners from Greece and Netherlands	Research on Integrated Nutrient Management (INM); Application of Farmer Field School to INM
Sustainable Tea; Sustainable Agriculture (2006-2012)	6 + Donors and Farmers	Smallholder tea Development Agency; Research, University and training bodies; Tea buying Company; Tea Certification Agency	Kenya; European partners from UK and Netherlands	Sustainability of smallholder tea; application of farmer field schools; smallholder tea certification
Green Water Credits 2011	5+ Donor	Research and development organisations; University, Government Ministry and parastatal	Kenya; European partners from Netherlands	Land management options;

The motivation to start each partnership was different in each case. Partnerships in OFEA started as informal communications, building on previous survey undertaken on adoption of Organic Farming practices in Kenya (1993) and on past awareness creation activities on organic farming practices (1986/87-1993). I was part of the research team that undertook the pilot survey on adoption of organic farming practices in Kenya and in creating awareness on farmers' perceptions of organic farming

(Kariuki *et al*., 1994). Through these initial efforts, I identified the need to undertake participatory research with smallholder farmers to further explore potentials and limitations of organic farming in Kenya, gather evidence-based data to inform practice and policy and to build synergistic and interdisciplinary partnerships. This led my co-authors and I to think of and initiate research partnership on organic farming with other like-minded organisations already in the field of sustainable agriculture. At the end of this research phase interesting results emerged (publications 6 and 7) and we identified gaps and direction for further research. Similarly my co-authors and I identified the need to up-scale research efforts to cover other agro-ecological zones and other countries where there was limited data on performance of organic farming and other low external input agricultural systems and to expand our research efforts on soil fertility management.

My co-authors and I relied on the initial contacts we made in OFEA phase to form a follower research partnership with organizations already promoting organic farming and low-external input agriculture and soil fertility in East Africa, those willing to work in partnerships and to pull resources and various disciplines together, and those working with NGOs, National Research institutions and universities and those able to raise funds and provide specific expertise. This broad based partnership endevour covering many countries, North-South partners and different disciplines gave birth to LEINUTS project (1997-1999) which fitted within the Proposal Call of the EU INCO-DC (International Cooperation with Developing Countries, 1994-1998) framework. I derive my publications 8, 12 and 14 from the context provided by LEINUTs Project. In this period there were also many scattered projects working on soil fertility in sub-Saharan Africa. Through the LEINUTS Project, we voluntarily joined together with these teams working on soil fertility in sub-Saharan Africa to form a network (NUTNET) that created synergy, among the multi-disciplinary teams in Africa, by providing an avenue for supporting soil fertility management at both field and policy level. The NUTNET network and the sister network “Enhancing soil fertility in Africa: from field to policy maker” provided avenues through which I compiled my publications 12 and 14 with data from LEINUTS Project.

Based on our experience with partnerships in the period 1994-2000/2001 that provided a solid methodological and institutional base for research into organic farming and low external input agriculture, soil fertility management and integrated nutrient management we identified a need to further strengthen research on soil fertility management and adoption of sustainable agriculture practices by bridging the gap between technology generation and uptake through farmer field schools; and building public-private partnerships to address the elements of markets and commercial activities with a potential to broaden the livelihood base for improving sound soil fertility management and sustainable agriculture practices. These ideas contributed to forming partnerships on farmer field schools on integrated nutrient management (INMASP Project); and on sustainable agriculture and tea production (publications 1-4, 9-11, 13 and 15).

Finally in a bid to enhance on-farm adoption of soil and water conservation practices, we undertook a study on the same in a partnership dubbed Green Water Credits. The motivation was to quantify costs and benefits associated with soil and water conservation practices to inform the design of a pilot project on Green Water Credits- an investment mechanism to support rainfed smallholders to strengthen land, soil and water conservation measures to reduce run-off, enhance rainwater infiltration and reduce soil evaporation (publication No. 5).

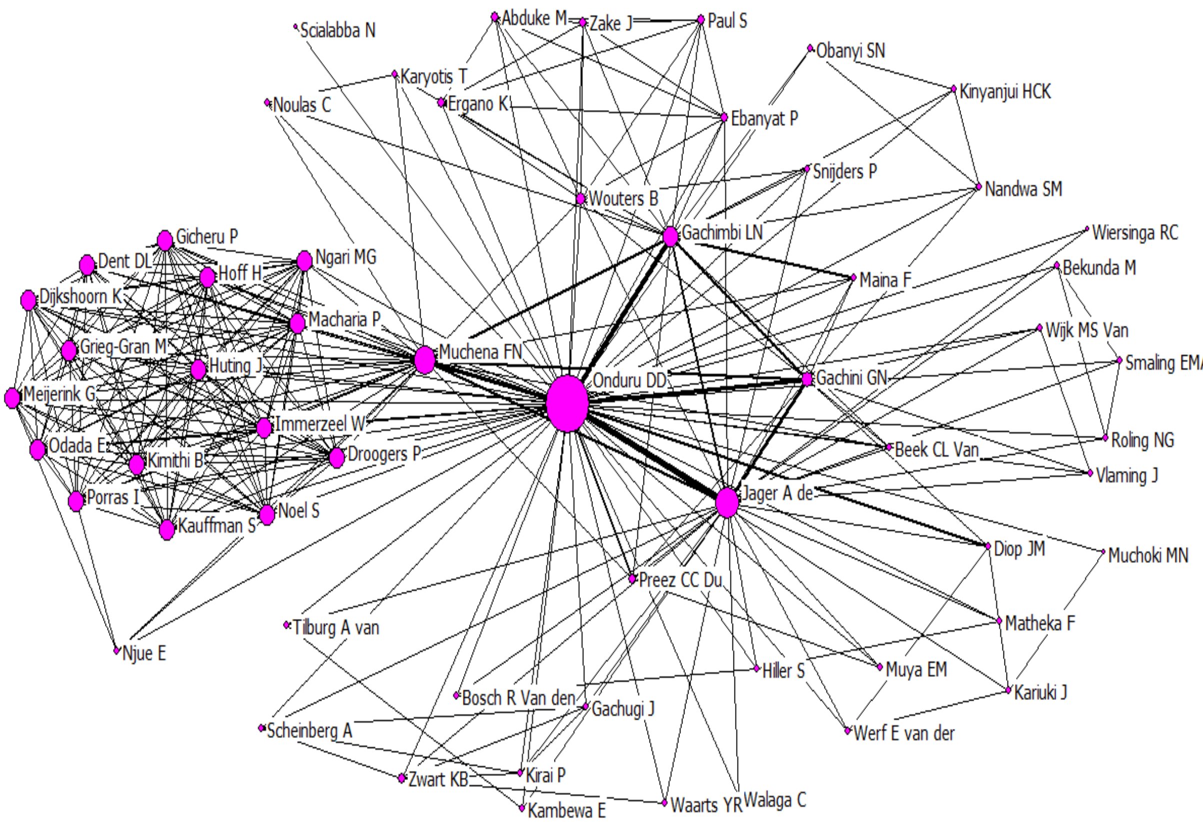
4.3. Productivity of my research partnerships

I analyse the productivity of my research partnerships based on the premise that collaborative interdisciplinary research can be understood as a social network where *collaborative leadership* manages knowledge mobility among research (network) partners in terms of publications; and where co-authorship of a publication is taken as a documented evidence of research collaboration indicating productivity and impact (Glänzel & Schubert, 2004). I have conceptualised my research social network to be researchers with whom I have worked together in different research partnerships over the last 20 years but with each of them having connections through co-authored publications to some or all researchers in my various research collaborations. This definition agrees with one given by Scott (2000) on the definition of a social network and one given by Cheong & Corbitt (2009) on co-authorship network, "….a social network consisting of a collection of researchers each of whom is connected to one or more other researchers if they have co-authored one or more papers".

I have used data from my co-authored publications in the period 1993-2012 to calculate co-authorship metrics and to draw a co-authorship network map to reveal the characteristics of this interdisciplinary research upon which this body of works is based. This agrees with previous studies where co-authorship is taken as a proxy measure of research partnership productivity (Gray, 2008). In this analysis I have used the terminologies research article, paper, publication and journal interchangeably. I have also done the same with the words author, co-author and researcher. Publication authorship metrics shows that key features of my research collaboration over the last 20 years are characterized by a mean of 4 co-authors per paper with an age weighted citation rate (AWCR) of 31. The latter "…measures the number of citations to an entire body of work, adjusted for the age of each individual paper" (Tarma Software Research Pty Ltd, 2013). Out of the total 68 publications produced in my collaborative interdisciplinary research partnerships (Table 5.2), 98.5% were co-authored, further indicating the strength of my involvement in interdsiciplinary research partnerships.

I have constructed a co-authorship network map by exporting my co-authored publication data from GoogleScholar as RefmanRis file format, cleaning it in note pad and importing it to BibExcel software (Persson *et al*., 2009) for further pre-analysis, followed by importing the output (net file) into UCINET software (Borgatti *et al*., 2002) for network visualization and analysis. I conceptualized the co-authorship network as a set of nodes (vertices or actors) indicating co-authors joined by edges (links or ties) showing research collaboration in co-authorship over the period 1993-2012. A link or an edge represents the fact that two authors have written at least one paper together. The vertices represent authors/researchers in the partnership. Thus, I conceptualized the co-authorship network as undirected network (Figure 4.1).

Figure 4.1: Co-authorship publication network based on degree centrality measure (1993-2012)



To analyse the co-authorship network, I first examine key characteristics of the co-authorship network as a whole. The network size was 60, indicating that there were 60 co-authors or researchers in my partnerships over the period 1993-2012 (Table 4.2). My experiences with this network size was that it did not limit relations within the network as a result of competition for research resources and funds or limit the capacity of each researcher to maintain links within the co-authorship-researcher network. This was partly so because of the clear partnership structures and expenditures framework developed in a participatory manner with all the partners at the beginning of each partnership; and also due to the fact that the partnerships operated at different project phases between 1993 and 2012, overlapping in some cases.

The network had an average geodesic distance of 3 (sd. 1.4) indicating that it was a dense collaborative research partnership network with moderate information flow which takes no more than three steps, on average, to reach every other researcher/co-author in the network. Geodesic distance is a measure of optimal path, distance or shortest possible walk between two actors (co-authors) in a network and gives an idea of how close the co-authors or actors are in the network (Hanneman & Riddle, 2005). Researchers who work as a team in collaborative research tend to have shorter average distances to other researchers in the same team (Newman, 2004).

An ego network compares nodes (co-authors) starting with one node (one co-author) and comparing it with the rest in the neighbourhood. I examined ego network data to make comparisons among co-authors starting with one co-author (ego) and comparing it with the rest in the co-authorship network. I made this comparison using ego network size, measures of centralities (degree and *betweennnes*) and brokerage capacity in the network and Eigen vector values. The latter however is another measure of centrality calculated from overall network data (Table 4.2). Ego network size is a direct count of the number of links that a co-author has to other co-authors in the network. Through the co-authorship network analysis (Figure 4.1 and Table 4.2), I have identified that I had the largest number of links to all others in the network with a network size of 59, putting me at an advantageous position to interact with the rest of the collaborators in the network and to offer collaborative leadership to partners in the network. However, there was large variability in ego network size with a minimum of one and a maximum of 59. The co-authors with one ego network size collaborated in one research partnership with one co-author leading to a single co-authored publication bearing the names of the two co-authors only.

Measures of centrality in a network define who is central with the highest link to other co-authors. A co-author is deemed central in a co-authorship network if he/she has the highest degree of connection or links in the network (degree centrality), if he/she is easily accessible to all other co-authors in the network (closeness centrality) and if such a person lies on several geodesics (shortest paths) between other co-authors in the network (*betweenness* centrality). From the ego network analysis, I have realized that I was among the three co-authors (co-authors 1, 2 and 5) with the highest degree centrality and *betweenness* centrality. This analysis confirms my understanding on how my interdisciplinary research collaborations and partnerships have operated since 1993. I was in a position to influence and be influenced by other co-authors in the co-authorship network (*degree* centrality). Figure 4.1 (co-authorship network diagram), further elaborates this position, graphically indicating my degree centrality, with the relative size of the circle showing the number of links to others in the network as well as my degree of collaborative leadership influence.

Table 4.2: Ego network data for co-authors in my research partnerships (1993-2012)

	Ego data					Eigenvector	Normalised eigenvector
No.		Size	Degree centrality	Betweeness centrality	Normalised broker		
1	Onduru DD	59	59	1127.133	0.92	0.577	81.595
2	Jager A de	30	30	175.367	0.91	0.46	65.105
3	Gachimbi LN	18	18	40.533	0.77	0.374	52.906
4	Gachini GN	12	12	11.367	0.63	0.369	52.166
5	Muchena FN	28	28	95.3	0.76	0.33	46.689
6	Preez CC Du	6	6	1	0.27	0.088	12.453
7	Diop JM	5	5	1.167	0.4	0.094	13.322
8	Maina F	5	5	0	0	0.088	12.486
9	Beek CL Van	5	5	0	0	0.11	15.511
10	Wouters B	11	11	7	0.6	0.064	9.114
11	Werf E van der	4	4	0.333	0.25	0.039	5.481
12	Kariuki J	4	4	1	0.5	0.022	3.055
13	Hiller S	4	4	0.333	0.5	0.046	6.544
14	Nandwa SM	5	5	0.667	0.45	0.044	6.18

		Ego data				Eigenvector	Normalised eigenvector
No.		Size	Degree centrality	Betweeness centrality	Normalised broker		
15	Meijerink G	18	18	2.6	0.53	0.032	4.516
16	Noel S	18	18	2.6	0.53	0.023	3.285
17	Porras I	18	18	2.6	0.53	0.032	4.469
18	Obanyi SN	4	4	0	0.25	0.03	4.267
19	Walaga C	2	2	0	0	0.031	4.319
20	Wijk MS Van	4	4	0	0.25	0.043	6.032
21	Vlaming J	4	4	0	0.25	0.043	6.032
22	Kinyanjui HCK	4	4	0	0.25	0.03	4.267
23	Muya EM	3	3	0	0.33	0.033	4.685
24	Kambewa E	3	3	0	0.33	0.031	4.45
25	Zwart KB	6	6	1	0.57	0.023	3.251
26	Tilburg A van	3	3	0	0.33	0.031	4.45
27	Paul S	7	7	0	0.45	0.026	3.688
28	Zake J	7	7	0	0.48	0.025	3.557
29	Ebanyat P	8	8	1	0.48	0.031	4.448
30	Ngari MG	17	17	0	0.48	0.018	2.513
31	Odada E	17	17	0	0.48	0.018	2.513
32	Njue E	5	5	0	0.35	0.015	2.069
33	Kauffman S	17	17	0	0.49	0.018	2.513
34	Kirai P	5	5	0	0.4	0.016	2.274
35	Gachugi J	5	5	0	0.4	0.016	2.274
36	Kimithi B	17	17	0	0.48	0.018	2.513
37	Macharia P	17	17	0	0.48	0.018	2.513
38	Matheka F	3	3	0	0	0.016	2.256
39	Snijders P	4	4	0	0.08	0.021	2.981
40	Smaling EMA	4	4	0	0.42	0.016	2.225
41	Roling NG	4	4	0	0.42	0.016	2.225
42	Waarts YR	3	3	0	0.17	0.016	2.207
43	Scheinberg A	5	5	0	0.4	0.016	2.274
44	Bekunda M	4	4	0	0.42	0.016	2.225
45	Ergano K	7	7	0	0.45	0.016	2.32
46	Abduke M	7	7	0	0.45	0.016	2.32
47	Wiersinga RC	2	2	0	0	0.015	2.159
48	Bosch R Van den	3	3	0	0	0.016	2.256
49	Noulas C	4	4	0	0.25	0.019	2.707
50	Muchoki MN	2	2	0	0	0.009	1.246
51	Scialabba N	1	1	0		0.008	1.201
52	Droogers P	17	17	0	0.48	0.018	2.513
53	Huting J	17	17	0	0.48	0.018	2.513
54	Immerzeel W	17	17	0	0.48	0.018	2.513
55	Grieg-Gran M	17	17	0	0.48	0.018	2.513
56	Hoff H	17	17	0	0.48	0.018	2.513

	Ego data						Eigenvector	Normalised eigenvector
No.		Size	Degree centrality	Betweeness centrality	Normalised broker			
57	Gicheru P	17	17	0	0.48		0.018	2.513
58	Dent DL	17	17	0	0.48		0.018	2.513
59	Dijkshoorn K	17	17	0	0.48		0.018	2.513
60	Karyotis T	4	4	0	0.25		0.019	2.707

I was also able to mediate in the communication channels in the network (*betweennes* centrality) and thus offered collaborative leadership in the partnerships as indicated by the highest *betweenness* centrality in the network (Table 4.2). This observation has further been corroborated by Nooy *et al*. (2011) who noted that a node (a co-author) that lies in many shortest paths among other pairs (*betweenness* centrality) has a potential to manage communication flows and channels, and by extension co-authorship arrangements and collaborative leadership in the network. My centrality in the co-authorship network and in offering collaborative leadership is further affirmed by high Eigenvector of geodesic distance values, which measures *closeness centrality* in terms of overall structure of the network based on factor analysis. *Closeness centrality* emphasizes how close a co-author (a node) is to all other co-authors in the network giving such authors a high potential to interact with others because he/she is close to all others (Uddin *et al*., 2012). Eigenvector is a measure of influence (closeness centrality) or leadership of a co-author in the network. It assigns relative scores to all co-authors (nodes) in the network based on the concept that connections to high-scoring nodes (co-authors) contribute more to the score of the node in question than equal connections to low-scoring nodes (Newman, 2004).

The idea of *betweenness* centrality is close to that of *brokerage* in a social network. I conceptualised brokerage in this analysis as that ego (co-author) who is the go-between for pairs of actors (co-authors) who are not directly connected to one another in the network. Brokerage measures brokerage potential while normalized brokerage measures the extent to which an ego (a co-author) is *really a broker* for a co-author can be in a brokerage position, but that could be just a small part of the connections (links) out of the total connections in the network (Hanneman & Riddle, 2005). From this analysis, co-authors 1 to 5 have the highest normalized brokerage index (0.63 to 0.92) with co-author No. 2 and I, heading the brokerage position. This is further a demonstration of collaborative leadership influence I played in the network by linking those who are not connected to others in the network and through these linkages tapping into new ideas on behalf of the network. Nooy *et al*. (2011) have noted that brokerage roles in a network include among others coordination, liason, gatekeeping, being a representative or itinerant broker. In my position I played the brokerage roles of coordination, liason and frequently being a representative in the network.

Appendix 5: Impacts of the Body of Works to Research and to policy

5.1. Background

In gauging the impacts of my body of works I have taken into consideration the view of Charlton (2006) who asserted that there is no formula on how to evaluate research impact and the definition of impact tend to vary with the discipline being considered and the interest of the actors. In pursuit of my objective in this Sction, I have not delved at depth at *ex ante* economic assessments ramiscient in literature that range from simple story-telling and anectodes to partial and compreshensive assessments of economic impacts of research (Maredia *et a*l., 2000). Rather I have examined the various dimensions of impact from a researcher and a practioner's point of view and from standpoint that impact measurement should not be done just for the sake of it, but to generate lessons that contribute to learning for improved science and development practice. In this section I look at bibliometrics as a quantitative measure of the impacts of my works to research and to policy. I have further used stakeholder and policy workshops to illustrate my attempts at policy dialogue.

5.2. Impacts on research and on academia

I have gauged the impact of this body of works to research and academic community based on quantifiable indicators from bibliometrics. Bibliometrics have been used in research and academic community to measure research progression and impacts, the production of knowledge and its use in future research and to influence policy and practice (Jarvey *et al.*, 2012). Bibliometrics, a set of methods to quantitatively analyse scientific and technical literature, include the "countables": number of publications, citations, h-index, number of patents etc. (Pendlebury, 2008). I have used Publish or Perish software (Tarma Software Research Pty Ltd, 2013) to calculate bibliometrics related to the publications included with this body of works and to my overall contribution that includes other publicly available publications and co-authored works. In the period 1997 to Quarter one 2013, there were 115 citations of these works included with this Context Statement (by 17.04.2013), Table 5.1. This indicates that these works were already in public domain, found useful, applied and impacted on work done by other researchers and develoment practioners. However, I note that the number of citations of this public works could have been influenced by a number of variables including accessibility of the specfic journals in which they were published and their impact factors, whether the articles were published as open-access or in pay-per-view form, the general quality and relevance of the research work and my motivation as a researcher to publish what, when and where among other factors and the motivation of other researchers to cite these works. Jenny Fry *et al.* (2009) has proposed that authors who cite others work may be motivated by a number of factors, namely persuasiveness, positive credit, currency, reader alert, operational information, social consensus and negative credit. Thus, the number of citations may increase with time depending on changes in attributes mentioned.

Table 5.1: Citation metrics for publications with this body of works (17.04.2013)

Year	Publication No (from Table 1)	Source	Publisher	Cites (No.)
1997	6	Biological Agriculture & Horticulture	agris.fao.org	15

1998	14	IIED	IIED	12
2001	12	IIED	IIED	15
2002	7	Biological agriculture & Horticulture	Taylor & Francis	11
2005	15	Land Use Policy	Elsevier	40
2005	8	International Journal of Agricultural Sustainability	Taylor & Francis	1
2006	10	Middle-East J. Scientific Research	idosi.org	0
2007	3	Agronomy for sustainable development	Springer	7
2007	4	International Journal of Agricultural Research	library.wur.nl	7
2007	2	Tropical Science	Wiley Online Library	3
2008	13	The International Journal of Sustainable Development and World Ecology	Taylor & Francis	2
2008	9	International Journal of Agricultural Sustainability	Taylor & Francis	2
2008	1	Journal of Crop Improvement	Taylor & Francis	0
2012	11	*In press**	isdsnet.com	0
2012	5	*In press**	In press	0
Total				115

Adapted from Publish or Perish Software Outputs, 17.04.2013; * Was in press at time of writing this Appendix.

I have gauged the overall impacts of my research work giving attention to all publications in the public domain since 1993 to date based on bibliometrics as calculated by Publish or Perish Software (Table 5.2). I have produced 68 public works on performance of smallholder agriculturere attracting a total of 338 citations with cites per paper averaging 4.97 times by first Quarter, 2013. This further corroborates my assertation that this body of public works have contributed to knowledge and made a positive impact on research, development practice and academia. At a personal level, I have applied the h-index to assess my accumulative impact of research output. The h-index is an index that attempts to measure both the productivity and impact of the published work of a scientist or a scholar and is based on a scientist's most cited papers and the number of citations that they have received in other publications (Hirsch, 2005). In the bibliometrics preseted in Table 5.2, an h-index of 9 was calculated implying 9 papers were highly impactful for they have been cited 9+ times. While h-index has been useful in comparing researchers impacts, how it correlates to academic advancement across different institutions and fields of study remain to be addressed. Similarly, its use has been contested as the length of the academic career will impact the number of papers published, the amount of time papers are available for citation and it may not accurately reflect the contribution of individually and highly cited papers (The University of Western Australia, 2013).

Table 5.2: Aggregate impacts of my research work (1994-Quarter 1, 2013)

Bibliometric indicator	Value of the indicator
Total Papers in public domain	68
Total citations	338
Years (period of publication)	20
Cites/year	16.90

Cites/paper:	4.97/2.0/0 (mean/median/mode)
Authors/paper:	3.90/4.0/4 (mean/median/mode)
h-index	9
hI,norm	4
AWCR (Age Weighted Citation Rate)	31.04
AWCRpA (Age weighted Citation Rate per Author)	8.25
Paper(s) with 1 author(s)	1
Paper(s) with 2 author(s)	7
Paper(s) with 3 author(s)	12
Paper(s) with 4 author(s)	30
Paper(s) with 5 author(s)	14
Paper(s) with 6 author(s)	4

Adapted from Publish or Perish Software Outputs on 17.4.2013

I'm pursuaded that research and academic knowledge production and dissemination cannot be measured only using the metrics discussed above. In an article on research impact measurement, The University of Western Australia (2013) has suggested that measures of esteem can also be used to gauge the impacts of research. These measures include, among others, partnerships, successfully acquited research projects and grants, awards and prizes, peer reviews etc. The body of public works presented with this context statement were peer reviewed. Partnerships and collaboration are discussed in Chapter 5.

5.3. Impacts on Policy

Through active involvement of farmers, extension agents, NGOs, researchers, the private sector and policy makers in a process of learning and effective change my research made attempt at influencing process of change and policy. The outputs of this research was presented in 13 regional workshops (1994-1999) attracting extension and development workers (15-30 per workshop) from Eastern Africa Region and in a concluding three-day seminar for reseachers, academia and extension staff. However, these dissemination efforts did not create a complete turn-around in the agricultural policy formulation realm, but succeeded in creating awareness and sensitation of various actors, and laid a foundation on which other actors are building on. For example, Kenya Organic Agriculture Network (KOAN) started lobbying Kenya Beureau of Standards (KEBS) to develop standards on compost and to exempt certified organic products from the S-Mark of quality requirement in Kenya.

This research process also attempted to create awareness to policy makers and wider stakeholders by organizing two "development Scenario" workshops at the District level. The formulated development scenarios, the conditions required for implementation and a prioritised action plan are presented for Nyeri district as an example (Table 5.3). The workshops were further meant to develop a consensus together with policy makers and various district stakeholders on what needs to be done to facilitate improved soil and farm productivity. The workshops attracted a total of 103 participants, sensitized policy makers and stakeholders on the status of nutrient balances, technological options available, current strategies used by farmers to manage their soils and current farm performance, and resulted in drawing up a workplan to overcome observed constraints. As a result of these workshops, one local Member of Parliament raised a question in the National Parliament on soil fertility related policies.

Table 5.3: Summarised results from development stakeholders' workshops in Nyeri: Scenarios

Key indicator	Business-as-usual	Low-input subsistence	INM-commercial
Agricultural production	• Gradual declining crop yields due to reduced manure input / availability • Reduced livestock production at farm level	• Stable yield levels	• Increasing yields; commercial crops • Increased output from livestock; especially milk
Economic performance	• Declining gross margins for crop and livestock	• Remaining relatively low levels of economic return • Increased importance of off-farm income	• Increased gross margins • High capital costs • Agricultural related off-farm income
Soil fertility	• Negative nutrient balances at farm and plot level and gradually declining soil fertility	• Slightly negative nutrient balances due to limited external inputs	• Higher in and out flows • Soil fertility maintained
Food security	• Food insecure; out migration	• Improved food security; vulnerable to climatic fluctuations	• Food secure for large group of people • Increased gap between rich and poor

Table 5.4: Summarised results from development stakeholders' workshops in Nyeri: pre-conditions for success

Scenario	Conditions
Business-as-usual	• No major changes
Low-input subsistence	• Effective low-external-input technologies are available making optimal use of existing resources and minimising nutrient losses. • Increased and more stable prices for food crops to make LEIA techniques attractive at farm level. • Investment in organic market segments for export.

	• Increased and more effective research and extension geared towards efficiency gains in low-external input techniques. • Sufficient off-farm income opportunities within the area are available to supplement low income levels.
INM – commercial	• Improved output-input price ratios • Large-scale promotion and support to implement livestock intensification system (zero-grazing systems). • Research and extension focus on INM technologies. • Facilitation of efficient marketing systems. • Facilitation of off-farm employment opportunities. • Focus and development on high-value crops and marketing of processed agricultural products.

Table 5.5: Summarised results from development stakeholders' workshops in Nyeri: summary of action plan

1	Establishing efficient and relevant information flows to farmers in a wide variety of technical issues concerning increased sustainable production methods in crops and livestock (much knowledge on the shelve currently not applied)
2	Increase availability of credits and making subsidies available for sustainable production techniques
3	Establishing organised market structures for inputs and outputs
4	Better targeted and timely implemented government policy to facilitate agricultural production such as land and price policies
5	Efficient and large-scale implementation of on-farm integrated nutrient management research
6	Facilitation of (rural) agro-industry development
7	Efficient soil analysis available to farmers at affordable prices
8	General community empowerment through training, information, group formation etc.
9	Further facilitation of soil and water conservation measures, including water harvesting
10	General improvement of infrastructure (roads, communications etc.)

From these initiatives I leant that while research at farm level is fundamental in generating knowledge, timely implementation of policies are also needed to effect change . At the time this work was done, policies were being formulated using a "top-down" approach by the Central Government Systems. Researchers, district stakeholders, civil society groups and farmers had little inputs. Nevertheless, the policy and implementation workplans drawn in the district workshops above were not implemented as desired. The workshops came too late into the process. A lesson learnt is that policy makers should be involved at an early stage in research process to effect any change and that dialogue with policy makers may at times be financially demanding. Another lesson is that there is need to develop tools to improve communication with policy makers so that research results can be presented in an easy to understand format with policy recommendations.

For future work on policy processes I have similar ideas as that Keeley (2001). I recommend the following:

- Build a network of actors for policy change that include grassroots people but also influential people so that the network can become a protagonist in a range of areas.
- Creating dialogue at field and district levels as well as at national and regional levels using bottom-up and top-down approaches at the same time.

- Development of success stories to persuade people about the merits of a research process and outputs. Success stories allow for exposure of a project and can be used as part of information exchanges to develop ideas and confidence on research results.
- Produce a range of outputs that document and capture project experiences and lessons
- Learn policy language and developing relevant tools for the same.

Appendix 6: Sustainability attributes, indicators and assessments

I have assessed sustainability of smallholder farming systems in Kenya by examining ecological, social and economic dimensions. For each dimension I selected specific attributes and indicators from my public works to determine the overall direction of agricultural sustainability of smallholder farming system in high and low-to-medium agricultural potential areas.

Measurements of sustainability indicators were either done at spatial scale (plot and farm level), at temporal scale (covering more than one agricultural season) or at both spatial and temporal scales. For this synthesis, I have made a distinction between temporal and spatial dimensions of sustainability analysis. I have done temporal analysis using indicators quantified over several seasons or years retrospectively or prospectively. This includes cases where the values of indicators were quantified through repeated measurements over time or one-time recall surveys with a time dimension (e.g. before and after studies, past historical trends, perceptions and estimation of future trends, repeated seasonal, annual or periodic measurements etc.). Although some of my public works have plot and farm level scale analysis, limited data availability and balance at these two scales limits separate synthesis and therefore determination and comparison of the direction of agricultural sustainability. I have therefore adopted a broad definition of spatial analysis of sustainability by using indicators quantified on “geographical spread” of smallholder farms (farm scale) without reference to time recall period.

I have selected soil chemical and biological indicators, namely soil pH, organic carbon, extractable phosphorus, exchangeable potassium and soil microbial carbon (Table 6.1). I have compared the specific values of these indicators with their respective thresholds derived from secondary data and expert systems to determine the direction of agricultural sustainability. Similarly, I have used nutrient balances as an indicator of soil and land quality with negative balances indicating losses, degradation or “unsustainability” and positive balances indicating accumulation. No threshold value exists for nutrient balances for the diverse farming systems in Kenya (see publication 11). For rainfall, I have used quantity and coefficient of variation as proxy indicators of sustainability. Rainfall has a major impact on productivity and stability of agriculture in Kenya where 98.2% of crop land is under rainfed agriculture (Karina & Mwaniki, 2011). A high coefficient of variation (≥ 30) indicates instability of production.

I have also selected maize crop productivity (e.g. publication 2 and 13) and tea green leaf yields (publication 11) to reflect quality of soil resource base, and temporal variability in yields (maize) to indicate dynamic changes in soil and climatic factors. To determine the direction of agricultural sustainability, I have compared on-farm maize and green leaf tea yields with relevant threshold values from literature for each research site. Under social and economic indicators, I have selected key indicators, which includes family earnings, gross margins, net farm income, total net benefits and net cash flows to indicate profitability (economic viability) of the farms studied. These indicators have been variously defined in my public works (see publication 3, 4, 7, 8, 9 and 10). Similarly, I have used Net Present Value (NPV) and Benefit Cost ratio to assess financial efficiency of soil conserving measures. NPV has a bearing on temporal dimension of sustainability (see publication 5). Various indicators associated with adaptability have also been used (See Table 6.1). In this case adaptability refers to integration of new innovations, accommodation of evolving learning processes and adoption of multiple ecological friendly technologies for enhancing sustainability of the farming systems (López-Ridaura *et al.*, 2002). I compared the values of the above indicators with proxy threshold values to determine direction of agricultural sustainability.

Table 6.1: Selected attributes and indicators of sustainability

Dimension of sustainability	Attribute	Indicator description	Measurement
Ecological (absolute evaluation)	Soil quality	pH (H_20: 1:2.5)	pH units
		Soil Organic C	%
		Extractable P	mg/kg
		Exchangeable K	cmol/kg
		Soil microbial carbon	% decline (cultivated vs. bush fallow)
		N-Full and partial nutrient balance	kg ha^{-1}
		P- Full and partial nutrient balance	kg ha^{-1}
		K- Full and partial nutrient balance	kg ha^{-1}
		N-soil stock depletion	% half $year^{-1}$
		P-soil stock depletion	% half $year^{-1}$
		K-soil stock depletion	% half $year^{-1}$
		Households experiencing soil fertility decline in the last 10 years	Percentage (< 50% = '+'; > 50%= '-')
	Crop productivity	Maize yields	25-year average (kg/ha)
		Maize yield stability	Coefficient of variation
		10-year maize yield trends	Scale: increasing (+), neutral (+-) and decreasing (-)
		Green leaf yields	Tonnes ha^{-1}
	Rainfall amount and distribution	Long rains amount	Mean (25 years)
		Long rains stability	Coefficient of variation
		Short rains amount	Mean (25 years)
		Short rains stability	Coefficient of variation
		Gross margins	Ksh ha-1 year-1 x1000
		Net Cash flow	Ksh ha-1 year-1 x1000
Social and economic	Economic viability	Family earnings	US$ half yr^{-1}
		Households below poverty line	percentage
		Net farm income	US$ half yr^{-1}
		Family earnings	US$ $year^{-1}$
		Share of off-farm income in family earnings	% of family earnings half yr^{-1}
		Total Net benefits	Ksh ha^{-1}
		Net Present Value	Ksh
		Benefit Cost Ratio	Ratio
		Percentage dependency on off-farm income	Percentage
		Percentage of households with insufficient income	Percentage
	Adaptability	Farmer perceptions-local farmer treatment	Scoring and ranking of treatments (farmer vs. new)
		Number of experiments before and after joining FFS	Count
		Adoption of good agricultural practices by FFS members	Count; diversity
		Sustainability scores	% change in scores: before and after FFS
	Self reliance	Households experiencing food shortage in the last 10 years	Percentage (< 50% = '+'; > 50%= '-')
		Changes in Social capital, group commercial activities and local institutional building	Scale; comparison of before and after FFS
		Changes in liveslihoods	Scale; comparison: before and after FFS
		Family labour self-reliance	Percentage of family labour in total labour demand in tea

I used three evaluation strategies based on selected and integrated use of the above indicators to determine the direction of agricultural sustainability: (i) absolute assessment in which I have used a selected mix of the above indicators to evaluate single farming system, publications 1, 2, 3, 4 and 5; (ii) relative or comparative assessment in which I have used selected set of the above indicators to compare organic (low external input agriculture) and conventional farming systems, publications 6, 7 and 8; and (iii) a mix of absolute and relative assessments (publications 9, 11, 12, 13, 14 and 15). These diverse evaluation strategies had been initially used in my public works and this Chapter only makes a synthesis of the outcomes to determine overall direction of sustainability.

I have classified the public works into two categories in an attempt to paint an overall picture of sustainability: publications based on research carried out in low-to-medium agricultural potential areas of Kenya (arid to semi-arid); and those from high agricultural potential areas of Kenya (sub-humid to humid), see Table 6.2 and Table 6.3. This provided a basis for separate determination of the direction of agricultural sustainability. I have used a scoring system to arrive at overall direction of agricultural sustainability based on the performance of the various indicators as contained in my public works. In the scoring system I have assigned one positive score (+1) to cases where the value of an indicator is “better or above” the threshold value and one negative score (-1) for the converse (Tables 6.2 and Table 6.3). Where the value of the indicator is comparable to the threshold value I have assigned a neutral score (0). To arrive at *“sustainability end point”* I have summed up all the negative scores and subtracted them from the positive scores separately for each area. When the aggregate score is positive, then the farming system is moving towards the right direction with increasing trend in agricultural sustainability while the opposite holds true when the aggregate score is negative.

Table 6.2: Sustainability assessment in low to medium agricultural potential areas of Kenya

Dimension of sustainability	Attribute	Public. No.	Time/space dimension	Description	Measurement	Value	Rating (-; +)
Ecological (absolute evaluation)	Soil quality	1	Spatial	pH (H_20: 1:2.5)	pH units	4.7	-
		1	Spatial	Soil Organic C	%	1.1	-
		1	Spatial	Extractable P	mg/kg	1.6	-
		1	Spatial	Exchangeable K	cmol/kg	0.47	+
		1	Temporal	pH (H_20: 1:2.5)	Change (% $year^{-1}$;decline)	7.4	-
		1	Temporal	Soil Organic carbon	Change (% $year^{-1}$; decline)	47	-
		1	Temporal	Extractable P	Change (% $year^{-1}$; decline)	47.2	-
		1	Temporal	Exchangeable K	Change (% $year^{-1}$; decline)	15.6	-
		1	Temporal	Soil microbial carbon	% decline (cultivated vs. bush fallow)	4.7	-
Ecological (Absolute evaluation)	Crop productivity	2	Spatial and temporal	Maize yields	25-year average (kg/ha)	0.7	-
		2	Temporal	Maize yield stability	Coefficient of variation	55	-
	Rainfall amount and distribution	2	Temporal	Long rains amount	Mean (25 years)	468	- ?
		2	Temporal	Long rains stability	Coefficient of variation	44	-
		2	Temporal	Short rains amount	Mean (25 years)	558	- ?
		2	Temporal	Short rains stability	Coefficient of variation	47	-
Ecological (Absolute evaluation)	Soil quality	3	Spatial	N-Full nutrient balance	kg ha^{-1}	1.1	+
		3	Spatial	P-Full nutrient balance	kg ha^{-1}	-1.7	-
		3	Spatial	K-Full nutrient balance	kg ha^{-1}	-5.4	-
		3	Temporal	N-soil stock depletion	% half $year^{-1}$	0.06	+
		3	Temporal	P-soil stock depletion	% half $year^{-1}$	-0.3	-
		3	Temporal	K-soil stock depletion	% half $year^{-1}$	-0.11	-
Socio-economic (Absolute evaluation)	Economic viability	3	Temporal	Family earnings	US$ half yr^{-1}	190	-
		3	Spatial	Households below poverty line	percentage	100	-
		3	Temporal	Net farm income	US$ half yr^{-1}	93	+

Dimension of sustainability	Attribute	Public. No.	Time/space dimension	Description	Measurement	Value	Rating (-; +)
		3	Temporal	Share of off-farm income in family earnings	% of family earnings half yr^{-1}	51	-
Ecological (Comparative evaluation)	Crop productivity	7	Temporal	Maize grain yields	Organic-kg ha^{-1}	2.4	+
					Conventional-kg ha^{-1}	2.0	
Socio-economic (Comparative evaluation)	Economic viability	7	Temporal	Total Net benefits	Organic-Ksh ha^{-1}	11597	+
					Conventional-Ksh ha^{-1}	5517	
Ecological (Comparative evaluation)	Productivity	8	Temporal	Grain yields	Low External Input Agriculture-Ksh ha^{-1}	224	-
					Conventional-Ksh ha^{-1}	399	
Socio-economic (Comparative evaluation)	Economic viability	8	Temporal	Net farm income	Low External Input Agriculture-US$ $year^{-1}$	538	+
					Conventional-US$ $year^{-1}$	334	
				Family earnings	Low External Input Agriculture-US$ $year^{-1}$	849	-
					Conventional-US$ $year^{-1}$	1356	
				Share of off-farm income in family earnings	Low External Input Agriculture- %	37	+
					Conventional-%	75	
				Percentage of income based on nutrient mining	Low External Input Agriculture- %	60	-
					Conventional-%	80	
Ecological (Absolute evaluation)	Soil quality	9	Temporal	Partial N balance-farmer treatment	Kg ha^{-1}	-21.6	-
	Productivity	9	Temporal	Maize yields-farmer treatment	Grain yields kg ha^{-1}	2530	-
Socio-economic (Absolute evaluation)	Economic viability	9	Temporal	Gross margins-farmer treatment	Ksh ha^{-1}	2104	+
	Adaptability	9	Temporal	Farmer perceptions-local farmer treatment	Scoring and ranking of treatments (farmer vs. new)		-

Dimension of sustainability	Attribute	Public. No.	Time/space dimension	Description	Measurement	Value	Rating (-; +)
Ecological (Absolute)	Soil quality	13	Temporal	Households experiencing soil fertility decline in the last 10 years	Percentage (< 50% = '+'; > 50%= '-')	77	-
	Productivity	13	Temporal	Farmer perceptions on 10-year trend in maize yield	Scale: increasing (+), neutral (+-) and decreasing (-)		-
Economic (Absolute)	Economic viability	13	Spatial	Percentage dependency on off-farm income	Percentage	32	-
	Economic viability	13	Spatial	Percentage of households with insufficient income	Percentage	87	-
	Self reliance	13	Temporal	Households experiencing food shortage in the last 10 years	Percentage (< 50% = '+'; > 50%= '-')	97	-

NB: Pub No = Publication Number

Table 6.3: Sustainability assessment in high agricultural potential areas of Kenya

Dimension of sustainability	Attribute	Pub No	Time/space dimension	Description	Measurement	Value	Rating (-; +)
Ecological (Absolute evaluation)	Soil quality	4	Spatial	pH (H_20: 1:2.5)	pH units	5.2	+
		4	Spatial	Soil Organic C	g/kg	16.5	+
		4	Spatial	Extractable P	mg/kg	22.5	+
		4	Spatial	Exchangeable K	cmol/kg	1.3	+
	Productivity	4	Spatial	Maize yields	$Kgha^{-1}$	119	-
Socio-economic (Absolute evaluation)	Economic viability	4	Temporal	Family earnings	US$ half yr^{-1}	396	-
		4	Spatial	Households below poverty line	percentage	80	-
		4	Temporal	Net farm income	US$ half yr^{-1}	154	-
		4	Spatial	Share of off-farm income in family earnings	% of family earnings half yr^{-1}	61	-
Socio-economic (Absolute evaluation)	Economic viability	5	Temporal	Fanya Juu-Net present Value	Ksh; 12% discount rate over 15 years; 1 US$= Ksh 88	1638 000	+
		5	Temporal	Fanya Juu-Benefit Cost ratio	Ratio; 12% discount rate over 15 years	1.1	+
		5	Temporal	Grass strips-Net present Value	Ksh; 12% discount rate over 15 years 1 US$= Ksh 88	3539 000	+
		5	Temporal	Grass strips-Benefit Cost ratio	Ratio; 12% discount rate over 15 years	7.8	+
Ecological (Comparative evaluation)	Crop productivity	7	Temporal	Maize grain yields	Organic-kg ha^{-1}	5.1	-
					Conventional -kg ha^{-1}	8.3	
Socio-economic (Comparative evaluation)	Economic viability	7	Temporal	Total Net benefits	Organic-Ksh ha^{-1}	2198 1	-
					Conventional - Ksh ha^{-1}	4612 9	
Ecological (Absolute + comparative)	Soil quality	10	Spatial	N-Full nutrient balance	kg ha^{-1} half $year^{-1}$ (Kibichoi)	-2.6	-

Dimension of sustainability	Attribute	Pub No	Time/space dimension	Description	Measurement	Value	Rating (-; +)
		10	Spatial	P-Full nutrient balance	kg ha^{-1} half $year^{-1}$ (Kibichoi)	36.7	+
		10	Spatial	K-Full nutrient balance	kg ha^{-1} half $year^{-1}$ (Kibichoi)	16.9	+
Socio-economic (Absolute + comparative)	Adaptability	10	Temporal	Farmer perceptions of own practice	Scoring and ranking of treatments (farmer vs. new)		-
	Adaptability	10	Temporal	Experiments before and after FFS	Comparison of number of individual experiments conducted before and after FFS		+
	Adaptability	10	Temporal	Adoption of practices by FFS members	Comparison of FFS-non FFS adoption of practices		+
	Self-reliance	10	Temporal	Changes in Social capital, group commercial activities and local institutional building	Comparison before and after FFS		+
	Adaptability	10	Temporal	Changes in livelihoods	Comparison before and after FFS		+
Ecological (Absolute + comparative)	Soil quality	11	Spatial	N-Partial nutrient balance	kg ha^{-1}	194	+
		11	Spatial	P-Partial nutrient balance	kg ha^{-1}	-20	+
		11	Spatial	K-Partial nutrient balance	kg ha^{-1}	28	+
	Productivity	11	Spatial	Green leaf tea yields	Tonnes ha^{-1} $year^{-1}$	6.8	-
Socio-economic (Absolute + comparative)	Economic viability	11	Spatial	Gross margins	Ksh ha^{-1} year-^{1} x1000	86.8	+
	Economic viability	11	Spatial	Net Cash Flow	Ksh ha^{-1} year-^{1} x1000	119.2	+
	Self reliance	11	Spatial	Family labour self reliance	Percentage of family labour in total labour demand in tea	80	+
	Adaptability	11	Temporal	Adoption of practices by FFS members	Comparison of before and after FFS		+

Dimension of sustainability	**Attribute**	**Pub No**	**Time/space dimension**	**Description**	**Measurement**	**Value**	**Rating (-; +)**
	Adaptability	11	Temporal	Sustainability scores	Percentage change in scores before and after FFS period	4	+
	Adaptability	11	Temporal	Changes in Social capital, group commercial activities and local institutional building	Comparison before and after FFS		+
	Adaptability	11	Temporal	Changes in livelihoods	Comparison before and after FFS		+

NB: Pub No = Publication Number

Appendix 7: My involvement in multi-stakeholder processes

Table 7.1: Overview of the multi-stakeholder processes

Country	Area	Topic of the MSP	Context	Process	Major outcomes	Publication No.
Kenya 1994-1999 OFEA/LEI NUTS	Low-to-medium; and high agricultural potential areas	Low-external input and organic farming	High costs of inorganic fertilizer inputs; Contribution of low external input and organic farming to livelihoods questioned; Mainstream agricultural research limited to conventional agriculture mandate	Establishment of community (research) groups as platforms for interaction PTD as form of interaction	○ Empowerment of stakeholders/farmers ○ Improved social relations ○ Increased confidence in conducting research on organic farming by mainstream organization ○ Change in attitude on low external input and organic farming practices	6, 7, 8
2001-2005 INMASP	Low-to-medium; and high agricultural potential areas	Declining soil fertility and farm productivity	Declining soil fertility; Bridging livestock-nutrient cycles; Inadequate application of farmer learning approaches in INM; Low milk production and poor market linkages (high potential areas)	Farmer field school platforms of interaction	○ Empowerment of stakeholders/farmers ○ Improved social relations ○ Improved soil management (INM strategies) ○ Establishment of self-help groups ○ Changes in attitude on soil fertility	1,2,3,4, 9, 10,12, 13,14,15
2006-2012 Sustainable Tea	High potential areas	Sustainability of smallholder tea Smallholder Tea certification	Low level application of sustainability enhancing practices by smallholders; Group certification of smallholder tea lacking	Farmer field schools; Certification of smallholder tea	○ Empowerment of stakeholders/farmers ○ Improved social relations ○ Enhanced sustainability of tea ○ Group certification of smallholder tea ○ Formation of smallholder (self-help) groups ○ Linkages with certified tea markets ○ Transparent inclusive decision making in tea-value chain	11

PART II: EVIDENCE OF ACHIEVEMENTS(SUBMITTED BODY OF WORKS)

See accompanying USB

Part IIa: **Spatial and temporal aspects of agricultural sustainability (Sub-theme 1)**

Part IIb: **Analysis of sustainability of organic and low external input agricultural systems (sub-theme 2)**

Part IIc: **Farmer learning for agricultural sustainability (sub-theme 3)**

Part IId: **Analysis of knowledge and perceptions on agricultural sustainability (sub-theme 4)**

PART II: EVIDENCE OF ACHIEVEMENTS (SUBMITTED BODY OF WORKS)

	Part IIa: Spatial and temporal aspects of agricultural sustainability
1	**Onduru, D.D**., Du Preez, C.C., De Jager, A and Muya, E.M., 2008a.Soil quality and agricultural sustainability of dryland tropical farming systems: A case study in Mbeere District, Eastern Kenya. *Journal of Crop Improvement* 21 (1): 79-100; DOI:10.1300/J411v21n01_06
2	**Onduru, D.D** and C. C. Du Preez. 2007a. Spatial and temporal dimensions of agricultural sustainability in semi-arid tropics: A case study in Mbeere District, Eastern Kenya. *Tropical Science* 47 (3):134-148; DOI: 10.1002/ts.207
3	**Onduru, D.D.** and Du Preez, C.C., 2007b.Ecological and Agro-economic study of small farms in sub-Saharan Africa. *Agronomy for Sustainable Development* 27: 197-208.DOI: 10.1051/agro: 2007003.
4	**Onduru, D.D.,** De Jager, A., Muchena, F.N., Gachimbi, L. and Gachini, G.N., 2007c.Socio-economic factors, soil fertility management and cropping practices in mixed farming systems of sub-Saharan Africa: A study in Kiambu, Central highlands of Kenya. *International Journal of Agricultural Research* 2 (5): 426-439.
5	**Onduru, D.D**., Muchena, F.N., Njuguna, E., Kauffman, S. 2013. Financial Efficiency and Intergenerational Equity of Soil and Water Conservation Measures in Kenya. *Greener Journal of Geology and Earth Sciences 1(2): 43-62.*
	Part IIb: Analysis of sustainability of organic and low external input agricultural systems
6	Werf van der, E., Kariuki, J.and **Onduru, D.D.,** 1997.Methodological Issues in Comparative Agro-Economic On-Farm Research Assessments of Organic versus conventional Farming Techniques. *Biological Agriculture and Horticulture* 14: 53-69.
7	**Onduru, D.D.,** Diop, J.M., Werf, E. Van der and De Jager, A., 2002.Participatory On-farm comparative assessment of organic and conventional farmers practices in Kenya. *Biological Agriculture and Horticulture* 19: 295-314
8	**Onduru, D.D.,** De Jager, A. and Gachini, G.N., 2005.The hidden costs of soil mining to agricultural sustainability in developing countries: A case study of Machakos District, Eastern Kenya. *International Journal of Agricultural Sustainability* 3 (3): 167-176
	Sub-theme 3: Farmer learning for agricultural sustainability
9	**Onduru, D.D**., C.C. du Preez, F.N. Muchena, L.N. Gachimbi, A. de Jager and G.N. Gachini., 2008b. Exploring options for integrated nutrient management in semi-arid tropics using farmer field schools: a case study in Mbeere District, Eastern Kenya. *International Journal of Agricultural Sustainability 6 (3): 208-228;* Doi:10.3763/ijas.2008.0267
10	**Onduru, D.D**., De Jager, A., Wouters, B., Muchena, F.N., Gachimbi, L. and Gachini, G.N., 2006.Improving Soil Fertility and Farm Productivity under Intensive Crop-Dairy Smallholdings: Experiences from Farmer Field Schools in the Highlands of Kiambu District, Central Kenya. *Middle East Journal of Scientific Research* 1 (1): 31-49

11	**Onduru,** D.D., De Jager, A. and Van den Bosch, R., 2012a.Sustainability of smallholder tea production in developing countries: Learning Experiences from Farmer Field Schools in Kenya *International Journal of Development and Sustainability* 1(3): 714-742
12	**Onduru, D**., De Jager, A., Gachini, G., Diop, J-M., 2001. Exploring new pathways for innovative soil fertility management in Kenya. Managing Africa's Soils No.25. IIED, UK
	Part IIc: Analysis of knowledge and perceptions on agricultural sustainability
13	**Onduru, D.D**. and Du Preez, C.C., 2008c. Farmers' knowledge and perceptions in assessing tropical dryland agricultural sustainability: Experiences from Mbeere, District, Eastern Kenya. *The International Journal of Sustainable Development and World Ecology 15 (2): 145-152.*
14	**Onduru, D.D**., Gachini, G.N. and Nandwa, S.M. 1998. Experiences in Participatory Diagnosis of Soil nutrient management in Kenya. Managing Africa's Soils No. 3. IIED, UK.
15	Muchena, F.N., **D.D. Onduru** and A. de Jager., 2005.Turning the tides of soil degradation in Africa: capturing the reality and exploring opportunities. *Land Use Policy* 22: 23-31. [doi: 10.1016/j.landusepol.2003.07.001]