Deutsches Institut für Entwicklungspolitik

German Development Institute

Discussion Paper 16/2017

Beyond the Agroecological and Sustainable Agricultural Intensification Debate: Is Blended Sustainability the Way Forward?

Jonathan Mockshell
Josey Kamanda

Beyond the agroecological and sustainable agricultural intensification debate: Is blended sustainability the way forward?

Jonathan Mockshell

Josey Kamanda

Bonn 2017

Discussion Paper / Deutsches Institut für Entwicklungspolitik
ISSN 1860-0441

Die deutsche Nationalbibliothek verzeichnet diese Publikation in der Deutschen Nationalbibliografie; detaillierte bibliografische Daten sind im Internet über http://dnb.d-nb.de abrufbar.
The Deutsche Nationalbibliothek lists this publication in the Deutsche Nationalbibliografie; detailed bibliographic data is available in the Internet at http://dnb.d-nb.de.

ISBN 978-3-96021-039-9

Printed on eco-friendly, certified paper

Dr Jonathan Mockshell, researcher, Department "Environmental Policy and Natural Resources Management", German Development Institute / Deutsches Institut für Entwicklungspolitik (DIE).

Email: jonathan.mockshell@die-gdi.de

Dr Josey Kamanda, Social Scientist (Innovation Systems Specialist), Africa Rice Center.

Email: j.kamanda@cgiar.org

Published with financial support from the Federal Ministry for Economic Cooperation and Development (BMZ)

Tulpenfeld 6, 53113 Bonn
☎ +49 (0)228 94927-0
🖷 +49 (0)228 94927-130
Email: die@die-gdi.de
http://www.die-gdi.de

MEMBER OF Johannes-Rau-Forschungsgemeinschaft

Abstract

With the Sustainable Development Goals (SDGs) has come a renewed global interest in ending hunger, achieving food security and preventing natural resource degradation. Despite this renewed interest and increased commitments to invest in agricultural development, there is an ongoing debate over the pathways to sustainability. The debate centres on sustainable agricultural intensification (SAI) and agroecological intensification (AEI) pathways to agricultural sustainability. Using a systematic literature review approach, this study examines the debate over AEI and SAI. This study employs a theoretical framework based on the economic, social, and ecological dimensions of sustainable agriculture within a policy and institutional space. Based on the sustainability dimensions, a discourse analytical technique is applied to unravel the debate. The results reveal that proponents of the SAI pathway are predominantly private sector actors, while support for the AEI pathway comes mainly from international donors, NGOs and civil society actors. Both pathways aim to promote food security; however, the actors differ on discourse relating to the concept of farming, the role of GMOs, the scale of operation, and land use, as well as views on the social, economic, and ecological dimensions of sustainability. Resolving these differences requires a blended sustainability approach that moves beyond the current AEI and SAI debate by acknowledging the tradeoffs and synergies of the socio-economic and ecological dimensions of the different pathways to sustainability. Knowledge platforms will support this shift, and an enabling policy and institutional environment will provide the right incentives to promote sustainable agriculture.

Keywords: sustainable agriculture, agroecological intensification, blended sustainability, systematic review

Acknowledgments

We thank the German Federal Ministry for Economic Cooperation and Development (BMZ) for funding this research through the collaborative project, “Promoting Food Security in Rural Sub-Saharan Africa: The Role of Agricultural Intensification, Social Security and Results-Oriented Approaches” in the “One World, No Hunger” special initiative. We would also like to thank Regina Birner, Michael Brüntrup, Ines Dombrowsky, Elke Herrfahrdt-Pähle and Justice Tambo for helpful comments and discussions that greatly improved the content of this paper. Further comments from Jonas Hein and Raoul Herrmann on earlier drafts of the paper are greatly appreciated. We are also grateful to our student assistants (Clara Dewes, Benoit Livrozet, Anna Rudolf, Nicole Anschell and Eva Zimmermann) for contributing literature research, data analysis and editorial work. The views expressed in this study are those of the authors and do not necessarily represent the view of the BMZ or the German Development Institute / Deutsches Institut für Entwicklungspolitik (DIE).

Bonn, June 2017

Jonathan Mockshell
Josey Kamanda

Contents

Figures

Tables

Boxes

Abbreviations

AEI	agroecological intensification
CAADP	Comprehensive Africa Agriculture Development Programme
CSA	climate-smart agriculture
FAO	Food and Agriculture Organization
FFS	farmer field schools
IPM	integrated pest management
SAI	sustainable agricultural intensification
SDG	sustainable development goal
SSA	Sub-Saharan Africa

1 Introduction

Achieving global food security remains an overwhelming challenge to development partners, researchers, policy makers and national governments (Fan & Brzeska, 2016; Foley et al., 2011; Godfray et al., 2010; Ochola et al., 2013). The situation is more complex today than ever before due to the challenges facing global food production systems (Godfray et al., 2010; Grote, 2014). Among these challenges is the increasing global population, which is projected to reach 8.5 billion by 2030, and 9.7 billion by 2050 (UN, 2015). Coupled with the limited amount and depletion of natural resources, the growing population pressure will raise global demand for food and drive up food prices, especially in transitioning and developing countries (Montpellier Panel, 2013). Furthermore, rapid urbanisation is encroaching on land and water resources that could otherwise be dedicated to food production (McIntyre, Herren, Wakhungu, & Watson, 2009; Wheeler & von Braun, 2013) and land set-aside for biodiversity conservation goals, thus the amount of land available for crop and livestock production is constantly decreasing (Vignola et al., 2015). At the same time, the rate of yield increases is slowing down, particularly in developed countries and high yield regions, possibly as a combined reaction of lowering efforts in agricultural research, limited public investment in the agricultural sector and increased environmental regulation (Ray, Mueller, West, & Foley, 2013). The increasing aggregate demand for food (which is estimated to grow by 40-80 per cent by 2050 depending on the exact number of people, their diet and food supply) will certainly have direct and indirect effects on food prices and food security (Wheeler & von Braun, 2013). In addition, global climate change is affecting food production and may create major challenges for achieving food security. This is particularly the case in low-income countries where food production has been impacted by extreme changes in temperature and rainfall patterns (Nelson et al., 2009; van Noordwijk, Hoang, Neufeldt, Öborn, & Yatich, 2011). At the same time, the agricultural sector is a contributor to climate change because of nitrogen fertiliser use and greenhouse gas emissions from livestock production (Pingali & Gerpacio, 1997; Pretty, 2008; Steinfeld, 2006; Tilman, 1999). There are many instances of interaction between agriculture and natural resource dynamics and stocks, such as water quantity and quality, terrestrial biodiversity, forests and landscapes.

Past initiatives have sought to address the challenge of increasing food production while reducing damage to the environment (von Braun et al., 2008; World Bank, 2003). This renewed interest is captured in the 2030 Agenda for Sustainable Development (UN, 2015). The second Sustainable Development Goal (SDG) aims at ending hunger, achieving food security, improving nutrition and supporting sustainable agriculture. The SDGs (6, 7, 12, 13, 14 and 15) of protecting, restoring and promoting sustainable use of terrestrial ecosystems, sustainably managing forests, combating desertification, halting and reversing degradation, stopping biodiversity loss, protecting water sources, and achieving sustainable consumption and energy use are all closely linked with agriculture. At the development cooperation level, several past and present initiatives have aimed to contribute to achieving food security and promoting sustainable agriculture. Examples of these initiatives are the British government's Foresight Projects, the German government's "One World, No Hunger", the United States Agency for International Development's (USAID) "Feed the Future" program, and the African Development Bank's Technologies for African Agricultural Transformation (TAAT) and High Five "Feed Africa" initiatives. African leaders have also committed to investing in agriculture under the African Union's Agenda 2063 and the Comprehensive Africa Agriculture Development Program (CAADP). CAADP aims to eliminate hunger and reduce poverty through the promotion of agriculture. To achieve this, African governments agreed in the 2003 Maputo Declaration to increase public investment in agriculture by a minimum of 10 per cent of their national budgets and to raise agricultural gross domestic product each year by at least 6 per cent for nations where agriculture plays a major role in the economy. In 2014, these commitments were renewed, specified and extended in Malabo. These global, regional and national initiatives show a strong consensus on the need to increase food production (Godfray et al., 2010; World Bank, 2008) and reduce the negative impacts of agriculture on the environment by adopting sustainable agricultural practices (Tilman, Balzer, Hill, & Befort, 2011; Zimmerer, Carney, & Vanek, 2015).

Despite the large number of initiatives and commitments made by a wide range of organisations, the goal of sustainable agriculture and what it entails is unclear to many actors and thus leaves room for self-determination of sustainable agricultural practices (see Hayati, Ranjbar, & Karami, 2010). Some actors argue for the continuation of technological advancements and intensive production systems through sustainable agricultural intensification (SAI) practices, while others push for a paradigm shift to eco-agriculture, agroecology or agroecological intensification (AEI). These views have contributed to ongoing public and scientific debate over AEI and SAI among stakeholders in the sustainable agriculture and food systems landscape. The debate is not merely academic in nature and cannot be expected to be settled on its own. The lack of consensus is consuming important resources in the development landscape and sustainability community. This has detrimental effects on agricultural policy processes and policy agenda setting in the food systems (see Mockshell & Birner, 2015), and it is even likely that the unsettled debate diverts resources from the sector to others that are less controversial.

The existing literature has highlighted the debate over AEI and SAI. Godfray (2015) examine the debate over sustainability and show that SAI can be classified into genetic intensification, socio-economic intensification and ecological intensification. Zimmerer et al. (2015) also jointly consider SAI and AEI as options for strengthening food security and ensuring environmental sustainability. The boundaries of ecological, sustainable and agroecological intensification have been found to be rather blurred by Wezel, Soboska, McClellan, Delespesse, & Boissau (2015). They point out that in a debate, there is a high chance that parties are referring to a similar term without understanding or acknowledging the differences in meaning they each hold (see also Garnett & Godfray, 2012). On the contrary, some authors argue that AEI and SAI cannot be lumped together (Parmentier, 2014) and the roles of “utopians” and “arcadians” have been examined by Struik and Kuyper (2014). These studies provide evidence of the unresolved debate about AEI and SAI and that it requires further unpacking and identification of the participants through a systematic review.

Thus, this review aims to disentangle the debate and contribute to its resolution. The study employs a theoretical framework based on the economic, social and ecological dimensions of sustainable agriculture. Using the three dimensions, a discourse analytical technique is applied to guide the data analysis. A systematic review through the lenses of a discourse analytical approach allows for the examination of the main differences between the actors in the AEI and SAI landscape and identification of the tradeoffs and synergies, and makes the debate more amenable to policy making. Following this introduction, the study is structured as follows: Section 2 examines the sustainable agriculture concept and presents a theoretical framework for analysing the differences between AEI and SAI. The research methods are described in Section 3. Sections 4 and 5 provide the results and discussion, respectively.

2 Sustainable agriculture and sustainability dimensions

This section briefly reviews the literature on the concept and principles of sustainable agriculture, some frequently-mentioned sustainable agriculture practices and the dimensions of sustainability.

2.1 Sustainable agriculture: concept and principles

The attempt to satisfy the food, feed and fibre needs of the world's growing population has led to unsustainable agricultural practices. Ensuring natural resource protection in the long run requires an urgent need to move to a sustainable agriculture development model. However, a sustainable agriculture model could well conflict with the future need for even greater food production and simultaneous environmental conservation. Sustainable agriculture uses holistic approaches focused on individual farming practices, such as knowledge-based development of whole farms and communities, to tackle the ecological, economic and social challenges of conventional agriculture (Ikerd, 1993). On a global scale, there have been proposals for moderate intensification – through adaptation and transfer of high-yielding technologies – focusing on "under yielding nations" to meet the increasing global food demand with minimal environmental impacts (Tilman et al., 2011).

While there is a general agreement that a shift to the sustainable agriculture paradigm is needed, different pathways to sustainability have emerged. These include AEI and SAI (Wezel et al. 2015, Struik & Kuyper, 2014). AEI is defined as the application of ecological science to the study, design and management of sustainable agriculture (Altieri & Nicholls, 2005). SAI is explained as "intensification using natural, social and human capital assets, combined with the use of best available technologies and inputs (best genotypes and best ecological management) that minimize or eliminate harm to the environment" (see Pretty, 2008). In the literature, AEI and SAI have often been viewed as two pathways to agricultural sustainability that are polar opposites (Godfray et al., 2010; Wezel & Soldat, 2009). In the past decades, several systemic approaches have emerged that bundle together sets of individual technologies. These practices and technologies are crop and farming system specific and can be classified under AEI and SAI pathways, as illustrated in Figure 1.

2.2 Frequently-mentioned sustainable agricultural practices

Some sustainable agriculture practices can be classified broadly under SAI and AEI. Organic agriculture can be classified under AEI, while climate-smart agriculture (CSA) can be classified under SAI. Systems of rice intensification practices and conservation agriculture can be classified under both SAI and AEI (Godfray et al., 2010; Wezel & Soldat, 2009). The classification is based on the specific set of sustainable agriculture practices (see Figure 1[1]).

Conservation agriculture (CA) is a "concept for resource-saving agricultural crop production that aims to achieve acceptable profits, high and sustained production levels while concurrently conserving the environment" (Friedrich, Derpsch, & Kassam, 2012) . The CA approach aims at "managing agroecosystems for improved and sustained productivity, increased profits and food security while preserving and enhancing the resource base and the environment" (FAO, 2015). CA is intended to be a holistic approach, characterized by numerous interactions among households, crops and livestock, to create a sustainable farming system (Hobbs, Sayre, & Gupta, 2008). The CA approach involves a wide range of practices that are part of its three main principles: the minimization of soil disturbance from mechanical tillage, the maintenance of a permanent organic soil cover (e.g. crop residues), and the diversification of crop species through crop rotation (Kassam, Friedrich, Shaxson, & Pretty, 2009). Because CA depends on natural biological processes and keeps the use of external inputs to a minimum, it contributes to the protection and expansion of biodiversity in the agricultural system.

The system of rice intensification (SRI) is based on a set of practices and principles that aim to increase the productivity of irrigated rice by changing the management of plants, soil, water and nutrients (IRRI, 2017). SRI has four main principles: early, quick and healthy plant establishment; reduced plant density; improved soil conditions; and controlled water application (SRI-International Network and Resources Canter, 2017). The SRI practices aim to help farmers to apply the principles in a way that suits their agroecological and socio-economic needs. Thus, practices such as mechanical weed control or hand picking of weeds are permitted. Further, although compost is preferred, inorganic fertiliser can also be used (see Figure 1).

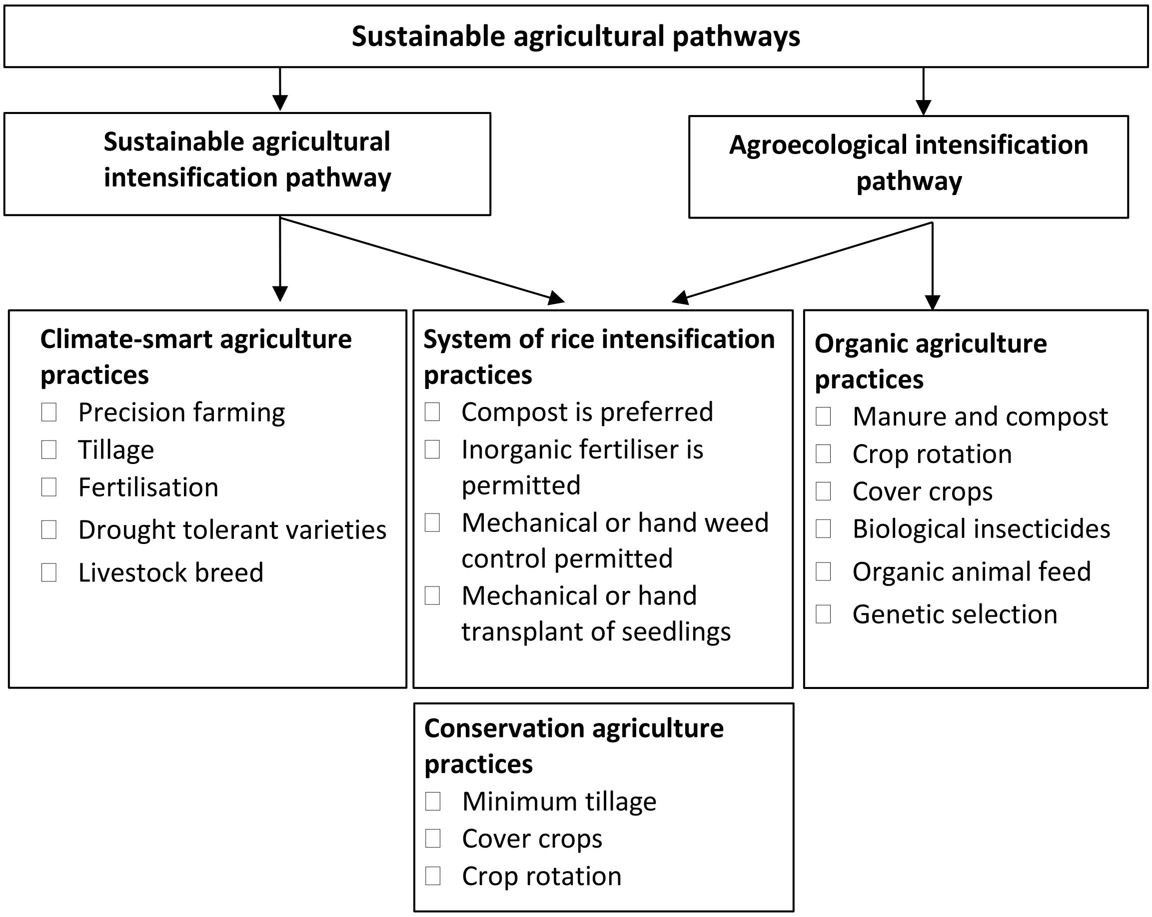
Organic agriculture (OA) is defined as a "holistic production management system [that] promotes and enhances agroecosystems health, including biodiversity, biological cycles and soil biological activity" (FAO, 2015). Organic agriculture abstains from the use of external inputs, such as agrochemicals and pesticides, genetically modified organisms, and veterinary drugs, and tries to reduce the impact on ecosystems as much as possible. Farmers practicing organic agriculture need to adapt to and work with their location-specific endowments and limitations (Scialabba & Müller-Lindenlauf, 2010). Organic agriculture practices include crop rotation, crop diversity, and the use of biological insecticides, organic manure, organic animal feed, genetic selection of crops and animals without GMOs, and experimentation with different combinations of crops. Some inorganic pesticides, for example sulphur and copper salts, are allowed under special conditions for crops and mechanization is often unregulated on some organic farms.

In contrast to conservation agriculture and organic agriculture, which contain a specific set of agricultural practices, CSA is defined by its envisaged outcome (Kaczan, Arslan, & Lipper, 2013). The general aim of CSA is to support the sustainable use of agricultural systems to attain food security and at the same time adapt to the impacts of climate change (Lipper et al., 2014). The Food and Agriculture Organization's (FAO) definition of CSA

1 Figure 1 highlights two sustainable agriculture pathways and frequently-mentioned practices. We acknowledge that there are several other emerging pathways. For example, CSA is considered a new sustainable agriculture pathway to deal with climate change issues. Further, some of the practices may overlap.

consists of three principal goals: to achieve an increase in agricultural productivity to support equitable increases in incomes, food security and development; to adapt to and create resilience from the farm level to the national level; and to reduce greenhouse gas emissions caused by agricultural production (FAO, 2013). These goals, largely aimed at achieving sustainable agriculture, are the focus of several research and development initiatives such as the Consultative Group for International Agricultural Research (CGIAR) Program on Climate Change, Agriculture and Food Security (CCAFS). The common practices of CSA include precision farming, tillage, slow-release of fertiliser, and use of drought tolerant varieties (CSA-guide-CCAFS, 2017).

Figure 1: Sustainable agricultural pathways



Source: Authors

2.3 Sustainable agriculture dimensions

Agricultural production has far-reaching impacts in many respects – it affects the quality of life of farmers and whole communities, natural resources (land, water, and biodiversity), and it impacts global climate as well as national economies and political systems. In order to capture the multi-faceted notion of "sustainability" in the context of agriculture, this study uses a framework in which agricultural systems can be analysed by means of three different dimensions, namely ecological, social and economic, within a policy and institutional landscape (see Figure 2). These different dimensions of sustainable agriculture highlight both tradeoffs and synergies within production systems. This framework is important for evaluating the performance of a production system in terms of its sustainability and for proposing transformational paths towards sustainable agriculture production. Based on a systematic literature review, Section 4 compares the discourses of different actors on the AEI and SAI pathways using indicators along the social, economic and ecological dimensions. The indicators also help in analysis of the potential tradeoffs and synergies. A similar framework has been applied by Yunlong and Smit (1994) to analyse the challenges to the sustainability of Chinese agriculture. An extensive literature review on the dimensions of agricultural sustainability and the associated complexity of finding acceptable measurement indicators has been analysed by Hayati et al. (2010). What follows is a brief overview of the social, economic, and ecological dimensions of agricultural sustainability.

Ecological dimension

The ecological dimension of sustainable agriculture focuses on the general aim that sustainable agriculture should establish agricultural practices that are environmentally sound, preserve resources and integrate natural biological cycles. This dimension also relates to land use practices, spatial arrangements, water use efficiency, nitrate presence, groundwater levels, crop types, soil nutrient content, the amount of fertiliser and organic manure used per unit of cropped land, as well as the amount of pesticides, herbicides and fungicide used (Hayati et al., 2010). In order to reduce environmental degradation caused by agriculture, agricultural practices should be assessed with regard to their impact on physical and biological conditions. Guiding questions for an ecological analysis might be

– Is the soil quality and fertility maintained by the current practice?
– Are the water sources used for irrigation sustainable, i.e. are natural cycles integrated?
– Are there chemical inputs affecting the quality of ground water?
– Are natural habitats, and thus biodiversity, conserved?
– Are energy inputs used in an efficient and climate-friendly manner?
– Are efficient recycling practices implemented?

Economic dimension

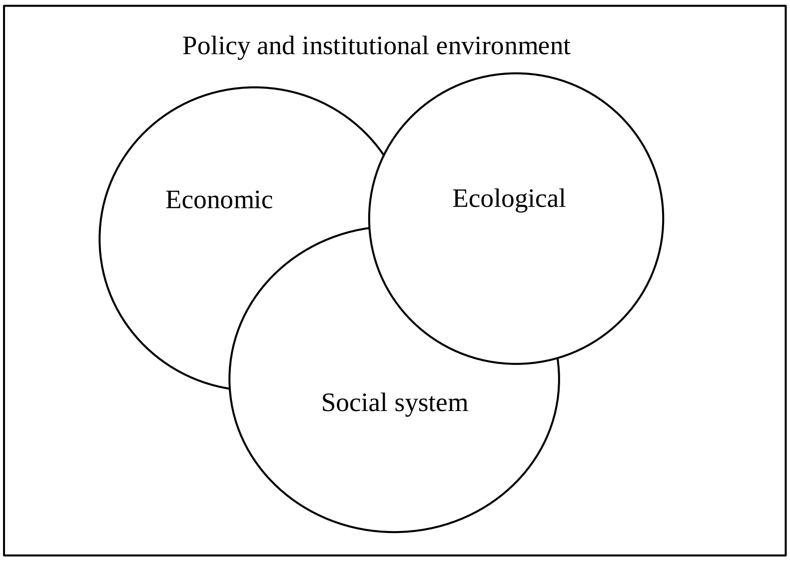
The economic dimension considers the general business viability and efficiency of a farming system. This includes crop productivity, net farm income, per capita food grain production and the benefit-cost ratio of production (Hayati et al., 2010). Additionally, costs from purchasing inputs (e.g. seeds, agrochemicals, fertiliser, etc.) and the dependence on other external inputs are critical issues under the economic dimension. Economic returns from farming should be high enough to provide farmers with adequate resources to maintain the productivity level of their farms and to ensure a long-term investment or planning horizon. Furthermore, farms should generate sufficient profit to guarantee a decent standard of living for the farmers and their families. That minimum standard of living is dependent on geographic circumstances; the comparison for farmers is non-farm incomes amended by risks, social costs and benefits. Thus, in the long run, one determinant of economic sustainability and to some extent of minimum sustainable farm size (given typical intensification and profitability) is non-farm economic development and distribution – a running target in many nations.

Beyond the question of the minimum farm size, the core concern of the economic dimension of sustainability is the question of how a farm's productivity level alters with the type of farming practiced. Farm size, crop type (cash or food crops), labour availability, labour productivity, and relative factor productivity are other elements influencing the economic dimension of sustainability. Conventional farming practices might increase a farmer's short-term benefits, but their potential consequences, such as land degradation or soil erosion, can negatively affect the productivity of the farm in the long run. Hence, a farm's productivity curve when applying conventional farming practices might be steeper than under sustainable farming in the short run. Whereas a "sustainable productivity curve" in its very essence is meant to rise progressively, the "conventional productivity curve" could start to decrease at some point as a consequence of land degradation or other negative repercussions. There is also a certain risk of a collective productivity curve decrease, for instance if excessive use of pesticides by (some) farmers creates resistance in pests.

Social dimension

The social dimension of sustainable agriculture considers the impacts of agricultural practices on the community, preservation of indigenous knowledge, livelihood support and social well-being. Sustainable farming should also protect the health and welfare of farmers, their workers and the surrounding community. In this respect, among the objectives of sustainable agriculture could be the creation of new employment opportunities as well as ensuring the existing ones, and the provision of health and retirement benefits. In addition, it is important to keep the question of intra- and inter-generational equity in mind: a farming practice should be designed to keep negative impacts on future generations to a minimum (e.g., in the form of increased production costs and degraded or polluted land).

Figure 2: Sustainability dimensions: economic, social, and ecological dimensions



Source: Authors

3 Research methods

This section describes the empirical research methods and data analysis techniques used in this study. First, the analytical framework is presented, then a sample of literature is given and the data analysis approach described.

3.1 Analytical framework: discourse analysis

The study employed a discourse analytical approach, an approach that has often proved useful in analysing conflicting topics and making the result of the analysis amenable to policy decision making. Hajer (2006, p. 70) describes discourses as "an ensemble of ideas, concepts and categories through which meaning is given to social and physical phenomena which is produced and reproduced through an identifiable set of practices". A discourse is made up of structures embedded in language and should be traced by the analyst (Hajer, 2006). Discourse coalition shows how a group of actors share a particular storyline or set of metaphors, both of which are constructed from existing discourses. A metaphor is an emblem or label of a general issue expressed in a way everyone understands (Hajer, 2006). The facts of an issue are expressed in a storyline, described as having a beginning, a middle and an end (Hajer, 2006). The identification of actors and the examination of metaphors and underlining storyline from the AEI and SAI literature guided the discourse analysis approach. Discourse analysis has played a critical role in analysing contested policy debates. Erjavec and Erjavec (2015) performed a discourse analysis of the 2014-2020 Common Agriculture Policy (CAP) reform documents. Mockshell and Birner (2015) have applied the discourse analysis approach in analysing agricultural policy discourses in Uganda and Ghana (see Mockshell & Birner, 2015) and agricultural policy narratives in Senegal (Mockshell & Birner, 2016). The actors and frame elements of the media coverage of the BSE (mad cow disease) crisis in Germany have been analysed by Feindt and Kleinschmit (2011). Following these examples, this study undertakes a systematic review of existing literature on AEI and SAI under the lens of a discourse analytical technique.

3.2 Sampling of literature

This study is largely based on a systematic review of literature on AEI and SAI. Systematic review is a technique that collects and critically analyses multiple research studies from different sources. In this case, the literature was mainly found in searches with Scopus and Google Scholar. The search and selection of literature for the analysis involved a two-step approach. During the first step of the search, the words "agroecological intensification" and "sustainable agricultural intensification" were searched separately in the Scopus database. The search results produced a total of 67 journal papers for "agroecological intensification" and 65 journal papers for "sustainable agricultural intensification". In the second step, the papers from the search outcome were carefully examined to check for the direct reference to "agroecological intensification" and "sustainable agricultural intensification". The papers were also screened for references to "agroecological practices" and "sustainable agricultural intensification practices". Some papers were rejected (AEI=54 rejected papers and SAI=47 rejected papers) as the content did not directly relate to the research question, although reference to "agroecological intensification" and "sustainable agricultural intensification" was made. After the screening, 18 published journal papers were selected for AEI and 13 published journal papers were selected for SAI. The data analysis was based on the selected papers after the screening.

3.3 Data analysis

Following selection, the papers were uploaded into ATLAS.ti software for analysis. A rapid auto-coding and then a detailed coding of reference to "agroecological intensification" and "sustainable agricultural intensification" were conducted. Next, a detailed matrix was created, based on the conceptual framework (see Figure 2) with reference to the economic, ecological and social dimensions of sustainable agriculture (see Table A1 of the Appendix). Each of the dimensions of sustainability were further divided by issue into sub-groups: ethics and human development, employment and services, efficiency, viability, and operational utility. Other emerging issues of vision, policy agenda, actors, role of science, land use, and views of proponents and opponents were fully examined during the coding of the themes and paragraphs of the sampled literature (see Table 1 and Table A1 of the Appendix). Questions relevant to each of the issues guided the coding process. Two people undertook the process of coding the text to ensure coding reliability. After the initial coding, the results were compared and refined to generate a single output from the analysis.

4 Results

This section presents the results of the analysis of AEI and SAI. Table 1 provides a summary of the differences between AEI and SAI. The detailed results from the literature analysis are presented in Table A1 of the Appendix. Besides the indicators introduced in Section 2.2, the main actors who support the two sustainable agriculture pathways and how they frame the concept and its vision are examined.

Table 1: Differences between AEI and SAI[2]

Indicators	**Agroecological intensification**	**Sustainable agricultural intensification**
Main actors	Non-governmental organisations (NGOs), civil society, researchers, academics	Governments, multinational private sector agribusinesses (agrochemicals, fertiliser, seed), researchers, academics, international development institutions
Concept	Increase agricultural output by capitalising on ecological processes that conserve natural resources in agroecosystems Use holistic approach to rural development including all environmental and human elements Employ set of practices to mimic nature View land husbandry as an "an ecology of disciplines"	Increase agricultural productivity while simultaneously protecting natural capital Focus on resource intensification and resource use efficiency Meet needs of present generation without compromising ability of future generations to meet their needs
Vision	Food security, pro-poor development, environmental sustainability Sustainable alternative to hegemonic style of conventional and agro-industrial agriculture	Food and nutrition security, poverty reduction, environmental sustainability Alternative to conventional intensification or industrial agriculture
Science	GMOs are not acceptable	GMOs are tolerated
Opposition	Viewed by opponents as "anti-science" and "do-nothing approach"	Viewed by opponents as "conventional and industrial agriculture model", "business as usual" and "an oxymoron"
Ecological dimension		
Land use	Land sharing (less land is set aside for conservation and less intensive production techniques are used to maintain biodiversity)	Land sparing (set aside land for intensive production and set aside part of the land for biodiversity)
Spatial arrangement	Mixed farming and multi-functional crops (e.g. cover crops, agroforestry), mixed crop-livestock systems	Monoculture
Landscape	Building resilient agroecosystems through ecosystem services	Minimizing damage to the environment through intensification rather than area expansion
Agricultural practices	Biological interactions in diversified farming systems to enhance productivity	Combining improved varieties and agronomy (good agricultural practices)
Economic dimension		
Efficiency	Land use efficiency (yield) Yield gap/yield potential Efficiency as a ratio (output per unit of input, e.g. water-limited potential)	Land equivalent ratios Farm or landscape productivity gap/possibility frontier
Seed system	Local seeds (own seed or seed sharing system)	External seeds (seed industry)
Input use	Low external input use (low cost)	High external input use (high cost)

2 Table 1 provides a summary of the literature analysis. See Table A1 of the Appendix for the full results.

Social dimension		
Knowledge generation	Local knowledge Participatory local knowledge generation	Expert knowledge and local knowledge
Farmers	Small-scale farmers	Large-scale farmers
Livelihood support	Livelihood support of small-scale rural households	Livelihood support of large-scale farmers
Source: Authors		

4.1 Agroecological intensification: actor landscape

The dominant stakeholders in the AEI landscape are farmer-based organisations, NGOs, academic researchers, international donors, and environmental groups aiming to reform food systems (Foran et al., 2014). According to Tittonell (2014, p. 54), grassroots organisations and environmental movements around the world are weary of the term sustainable intensification as they often see it used as a "window-dressing, green-washing strategy" to justify agricultural intensification, that is "a wolf in sheep's clothing" (Collins & Chandrasekaran, 2012). NGOs have a long history of supporting the agroecology pathway to sustainable agriculture. As Altieri (2002, p. 2) noted, "non-government organizations have long argued that a sustainable agricultural development strategy that is environmentally enhancing must be based on agroecological principles and on a more participatory approach for technology development and dissemination, as many agree that this may be the most sensible avenue for solving the problems of poverty, food insecurity and environmental degradation". The dominant role of NGOs, such as SOCLA[3] and La Via Campesina,[45] in the agroecology landscape is not surprising as the agroecology pathway emphasises bottom-up and farmer-led participatory approaches. In the case of La Via Campesina, agroecological practices are a pillar of their sustainable peasant agriculture (Tomich et al., 2011).

4.1.1 Agroecological intensification: concepts and vision

The agroecology concept has developed through an attempt to integrate the principles of ecology and agronomy (Francis et al., 2003; Tittonell, 2014). Agroecology first appeared in publications in the 1930s and has evolved as a set of practices, a social movement and a scientific discipline (Wezel & Soldat, 2009). As a scientific discipline, the term refers to the application of ecological concepts and principles to the design and management of sustainable food systems (Francis et al., 2003; Gliessman, 2016). Agroecological practices aim to mimic natural processes to reach beneficial biological interactions and synergies among the components of the agroecosystems (De Schutter, 2010). Ecological intensification is based on "managing service-providing organisms that make a quantifiable direct or indirect contribution to agricultural production" (Bommarco, Kleijn, & Potts, 2013, p. 230). It involves "the use of biological regulation to manage agroecosystems, at field, farm and landscape scales" (Doré et al., 2011, p. 197). More recent definitions have explained the concept as an integrative study of the ecology of the entire food system, encompassing

3 Spanish acronym for the Latin American Scientific Society of Agroecology (Tittonell, 2014)

4 A network of farmers, peasants and food workers from 69 countries (Foran et al., 2014)

5 We acknowledge that the view of La Via Campesina is not representative of all farmer groups.

ecological, economic and social dimensions (Francis et al., 2003). The concept uses a holistic approach to take into account all relevant aspects of sustainability and it is based in the study of traditional peasant agriculture (Gliessman, 2016; Tittonell, 2014). The agroecology concept aims to serve as an alternative to the hegemonic style of conventional agriculture and to make farming more ecologically sustainable (De Ataíde Cândido, Moura Nóbrega, Martins De Figueiredo, & Souto Maior, 2015). Furthermore, this pathway endeavours to change the attitudes and philosophies among decision makers, scientists and others to acknowledge and promote alternative farming approaches (Altieri, 2002). Box 2, which is based on Wezel et al. (2015), summarises the key concepts of AEI. Other approaches that are closely aligned with the AEI concept are conservation agriculture and organic agriculture.

Agroecological farming in particular focuses on community-based bottom-up approaches, in which farmers use their traditional knowledge and actively participate in the design of new agricultural systems (Tittonell, 2014; Wezel, & Soldat, 2009). This idea of designing new agricultural systems also connotes the idea of agroecology as a movement (Tittonell, 2014), and includes farmer groups working for food security or environment groups advocating for alternative farming systems. Tittonell (2014) highlights the example of SOCLA with its large member base and its drive for technological and institutional innovation. As a practice, agroecology relies on few external inputs, rather applying techniques to recycle nutrients and energy on a farm. Crop and livestock systems are integrated and crops are diversified to synthesize interactions within the agricultural system (De Schutter, 2010). Proponents of agroecology argue that because farmers in low-income countries lack access to external inputs and most are food insecure, agroecology offers a radical shift to help increase agricultural production (Altieri, 2002). The idea is emphasized in the food self-sufficiency narrative, which emphasizes local production to meet domestic food consumption rather than food imports. Proponents of AEI argue that agroecology fulfils this concept and this ensures food security in rural areas. Further, supporting farmer-led innovations, ending agricultural subsidies to industrial farms, reversing free trade deals, reducing the power of dominant players to speculate and hoard, and promoting agrarian reforms have been critical issues in the agroecology discourse (Foran et al., 2014, p. 88). Tolerance for GMOs is a divisive subject in the debate. According to the proponents of agroecological practices, the use of GMOs undermines farmers' independence from the agro-industry, since farmers are unable to (re)use their own seeds. Utilising GMOs is also said to restrict farmers' realm of experimentation with the given local ecological conditions and thus counteracts the agroecological aim to encourage traditional farming practices. However, there are differences in perspectives among proponents of agroecology as well. For example, some argue only for the balanced and efficient use of fertiliser, quality hybrid seeds and high yielding varieties (Doberman & Nelson, 2013; Wezel, et. al., 2015); while others argue that only agroecological practices (low-tech and low external input use) will reduce the food insecurity problem, particularly in low-income countries (Gliessman, 2016; Tittonell, 2014; Tomich et al., 2011).

4.1.2 Agroecological intensification: practices

Agroecological approaches are based on farmers' knowledge and experimentation and most of the practices of agroecology existed before the concept of agroecology was developed. Agroecological approaches include several practices aimed at harnessing the potential of agriculture and ecological processes to improve agricultural yields (Altieri & Toledo, 2011;

de la Rosa, Anaya-Romero, Diaz-Pereira, Heredia, & Shahbazi, 2009; Fonte et al., 2012; Rolando et al., 2017). The practices include: no or minimum tillage to improve soil structure (conservation tillage); integrated pest management (IPM) practices and biological strategies (Wezel et al., 2015); the judicious use of pesticides (Doberman & Nelson, 2013); agroforestry; water conservation through efficient water harvesting; balanced use of fertiliser (Doberman & Nelson, 2013); integrated nutrient management through the use of compost and nitrogen-fixing crops; and crop-livestock integration (see Box 1).

Existing studies have also confirmed the importance of farm diversification. Pretty, Toulmin, & Williams, (2011) show that the diversification of farms results in the emergence of new crops, livestock or fish that, in turn, adds to the local food supply. Pretty et al. (2006, p. 1114) also noted that "although it is uncertain whether these approaches can meet future food needs, there are grounds for cautious optimism, particularly as poor farm households benefit more from their adoption". Return to labour and income in the agroecology pathways remains contested. However, there is a general conclusion that the diversity of crops and animals in agroecological approaches improve income and the food and nutritional status of farm households (Altieri, 2002; Tomich, et al., 2011). Through the application of farmer-to-farmer learning in farmer field schools (FFSs), agroecological approaches promote social learning among farmers. As Pretty et al. (2011, p. 12) noted, "all IPM programs have aimed to build social and human capital through the widespread use of FFSs (in West Africa, for example, 3,500 FFSs have been held and these have trained 80,000 farmers)". Such training is also more likely to translate into increased yield and incomes.

Box 1: Agroecological intensification practices
General agroecological intensification practices • Mulching, intercropping, crop rotations, (Doberman & Nelson, 2013; Côte et al., 2010; Karamura et al., 2013; Milder, Garbach, DeClerck, Driscoll, & Montenegro, 2012; Ochola et al., 2013). • Integrated soil and nutrient management, including conservation agriculture (Doberman & Nelson, 2013) • Soil and water conservation (Doberman & Nelson, 2013; Côte et al., 2010; Karamura et al., 2013) • IPM and biological control strategies (Côte et al., 2010; Karamura et al., 2013) and the judicious use of pesticides (Doberman & Nelson, 2013; McCune et al., 2011) • Use of organic inputs and balanced and more efficient use of fertilisers (Côte et al., 2010; McCune et al., 2011; Karamura et al., 2013; Milder et al., 2012; Ochola et al., 2013)
Source: Wezel et al., 2015, p.1290

4.2 Sustainable agricultural intensification: actor landscape

The SAI landscape is dominated by the private sector.[6] The main actors using the term "sustainable agricultural intensification" include organisations such as USAID, the International Fertilizer Industry Association (IFA), the Consultative Group for International Agricultural Research (CGIAR), the Montpellier Panel, the World Economic Forum (WEF), the Feed the Future program of USAID, Sustainable Development Solutions Network (SDSN) and the Bill and Melinda Gates Foundation (Tittonell, 2014).

6 We acknowledge that some NGOs and civil society organisations promote SAI technologies, such as fertiliser use, mechanisation and use of improved seeds.

Agrochemical companies have often referred to SAI or sustainable agriculture in their official communications. For example, BASF has used sustainable agriculture and SAI explicitly in their communication (BASF website, 2017), while Bayer Crop Science has used the broader term, sustainable agriculture (Bayer website, 2017).

4.2.1 Sustainable agricultural intensification: concepts and vision

SAI has become a popular concept in the quest to fix the current agricultural production systems, increase food production and minimise damage caused by farming on the environment (Wezel et al., 2015). The use of the term can be traced back to a 1983 workshop report on the effects of SAI on tidal swampland agroecosystems in Indonesia (Wezel et al., 2015). Since then, the concept has been defined in a number of ways by several authors, and the various definitions remain contested. Godfray (2015) defines SAI as "a process designed to achieve higher agricultural yields whilst simultaneously reducing the negative impact of farming on the environment". The concept of SAI places emphasis on technology adoption, resource use efficiency and resource intensification to increase productivity and reduce damage to the environment (Gliessman, 2014; Struik, Kuyper, Brussaard, & Leeuwis, 2014; Vanlauwe et al., 2014).

While proponents of the agroecology pathway have tried to separate agroecology from SAI, proponents of SAI have done the reverse. Some authors have classified SAI into dimensions of genetic intensification, ecological or agroecological intensification and socio-economic intensification (Godfray, 2015; Montpellier Panel, 2013). The ecological intensification dimension of SAI promotes the adoption of farming systems whose practices make better use of natural resources and reduce harm to the environment. It consists of practices that establish a synergy between agriculture and environmental elements (Montpellier Panel, 2013) including IPM practices, conservation tillage, alley cropping, and the use of legumes and nitrogen-fixing crops, as well as soil conservation techniques. Socio-economic intensification involves the provision of economic incentives and income for farmers (Montpellier Panel, 2013). The socio-economic dimension of SAI focuses on creating an enabling environment. It underlines the importance of developing input markets to increase farmers' access to farm inputs and output markets for farmers to sell their produce. Farmers' access to markets is essential to increasing their income and reducing rural poverty. Such socio-economic incentives also promote human capital development as farmers can pay for their families' health care and education, and attain household nutrition security.

Genetic and technological intensification highlight plant and animal breeding techniques (Godfray, 2015). Different methods are employed to increase crop and livestock yields and develop breeds that are resilient to extreme climatic events, such as drought. The breeding process includes both modern (e.g. genetic modification, marker-assisted selection, cell and tissue culture) and conventional techniques. The tolerance of GMOs is one of the highly contested issues in the SAI debate. As Godfray (2015) states, "the use of GMOs is one of the most divisive and contentious issues in current discussions of farming, and sustainable intensification has been placed on one side of this grand fault line because of its willingness to countenance genetic engineering". Those who are proponents of agroecological approaches view the use of GMOs as the separating factor between agroecological farming and SAI. For opponents of GMOs, the use of GMOs and the dependence on external inputs is considered to be "business as usual" and represents industrial farming. [7]

4.2.2 Sustainable agricultural intensification: practices

Box 2 explains some of the main practices of SAI. Similar to AEI, SAI practices include practices such as conservation tillage, improved crop rotation and application of living and residual mulches for soil coverage. However, SAI accommodates other "smart" farming practices, such as precision farming, which is highly dependent on technologies like satellite imagery, information technologies and geospatial tools (Montpellier Panel, 2013). Precision farming approaches can be applied to soil preparation, harvesting, livestock farming, seeding, and crop management practices, such as the application of fertiliser. Although high technology approaches, such as precision farming, are not applicable to smallholder farmers in Sub-Saharan Africa (SSA), other practices such as micro-dosing of agrochemicals are accepted practices in SAI recommended for use in developing countries.

Box 2: Sustainable agricultural intensification practices

General sustainable agricultural intensification practices:

- Conservation tillage (McCune et al., 2011; Côte et al., 2010; Reardon, Barrett, Kelly, & Savadogo, 1999), improved crop rotations and the application of living and residual mulches for soil coverage (FAO, 2011; Matson, Parton, Power, & Swift, 1997)
- Use of legumes, cover crops and catch crops in rotations (Sumberg, 2002; Tilman et al., 2011), alley cropping (Pretty, 1997; Raintree, 1986) and IPM (Pretty, 1997; Pretty et al., 2011; Reardon et al., 1999)
- Soil conservation (FAO, 2011; McCune et al., 2011)

More specifically:

- Use of worm composts (McCune et al., 2011), on-farm mechanisation (Friedrich et al., 2012; Grote, 2014), smarter, precision technologies for irrigation and nutrient use efficiency (FAO, 2011), use of high yielding varieties, including transgenic crops and animal-crop integration (McCune et al., 2011)

Source: Wezel et al. (2015, p.1289)

5 Discussion

The purpose of this study is to contribute to the debate over AEI and SAI by identifying the actors and unpacking the ongoing discourses. As highlighted in the results, the main actors in the AEI and SAI landscape differ from each other, creating a "coalition" or community of practice for SAI on the one hand and AEI on the other. As discussed in Section 3.1, a discourse coalition consists of a group of actors sharing a particular storyline over an extended period of time. In the case of the AEI and SAI debate, the individual coalitions share similar discourses and often advocate for the same specific farming practices.

In the discourse, proponents of SAI criticise the concept of AEI as being synonymous with a "do-nothing approach" and "anti-science" and having potentially negative consequences on the goal of ending hunger and achieving food security. The discourse on land sharing

7 The debates over GMOs, agrochemicals, and fertiliser are not just between proponents of AEI and SAI but also within each of the paradigms, although the inter-differences are larger than the intra-differences.

versus land sparing has been a controversial part of the sustainable agriculture and food production debate (see Fischer et al., 2013). In the land sparing strategy the focus is on setting aside some land for intensive productions and setting aside some land for biodiversity and conservation (Fischer et al., 2013, p. 1). The land sharing strategy focuses on less intensive production techniques to maintain biodiversity throughout the production process (Fischer et al., 2013, p. 1). Proponents of SAI argue that land sharing leads to extensification, which can have a potential impact on biodiversity loss and contribute to climate change. Similarly, the land sparing argument, which favours the use of external input and modern technology to increase production, is also criticised by proponents of AEI for causing damage to the environment due to external input use. Considering the arguments of the land sparing and land sharing strategies in the debate, there are clear tradeoffs as well as potential synergies of both AEI and SAI on the economic, social and ecological dimensions of sustainability.

Based on the economic dimension of sustainability, increasing productivity through land sparing might have economic (e.g. increased income), food security and social benefits (e.g. improved livelihood), but might also have some environmental consequences (e.g. excessive use of inorganic chemicals). Similarly, increasing production through land sharing might have some social (e.g. improved livelihood) and environmental benefits (e.g. improved land management practices and biodiversity protection), but could have environmental (e.g. land extensification) and economic challenges (e.g. reduction in income in the initial phase). These examples suggest some tradeoffs among the different dimensions of agricultural sustainability and have a potential impact on a farmer's decision to adopt an AEI pathway (e.g. organic agriculture practices), an SAI pathway (e.g. CSA practices) or blend the two (e.g. SRI and CA practices). However, these tradeoffs are often neglected in the debate, thus making AEI and SAI highly controversial topics in both the scientific and policy arenas (see Struik & Kuyper, 2014).

The tolerance for GMOs in SAI and its unacceptability in AEI are very much at the centre of public and scientific debate and may continue to be for the foreseeable future. The debate is influenced by differences in beliefs and ideology (see Struik & Kuyper, 2014; Mockshell & Birner, 2015). The extent to which belief plays a role in the debate has not been analysed in the literature. This belief dimension, coupled with the identified tradeoffs and other aspects of agriculture (e.g. agroecological factors, labour, price, trade, standards, etc.) creates a challenge, and makes it practically impossible to agree on a single set of sustainable agriculture practices. The lack of consensus is also evident in how diverse the literature and actors are on the sustainability debate, although attempts have been made to bring the diverse views together, efforts remain theoretical (see Godfray, 2015; Montpellier Panel, 2013). The question of how much attention to pay to the economic or productivity gains in contrast to the ecological and social dimensions of sustainable agriculture are fundamental issues that will require more rigorous scientific analysis and evidence to resolve. Such evidence can feed into policy processes to help find policy solutions. The scientific analysis could cover the productivity gains, income, environmental impact, cost-benefit analysis and studies on the policy and institutional support. The results from such empirical analysis will provide evidence to inform policy makers and create public awareness of the AEI and SAI pathways to sustainability. Further, it is essential to move beyond the current impasse of having proponents and opponents of the different sustainability pathways, and rethink the potential synergies and the complementarities of the pathways to bringing farming systems to a blended sustainability. The blended sustainability concept carries the idea of examining the dimensions of the different farming pathways and practices, and aligning the strengths and weaknesses of AEI and SAI pathways to harness synergies and reduce tradeoffs. For example, modern technologies in the SAI pathway can be promoted to benefit small farms economically, while the ecological intensification practices in AEI can be adopted to make farming systems more ecologically sustainable. With current technological advancements, one cannot ignore the interaction between modern technology (e.g. digital farming) and indigenous knowledge and their role in promoting sustainable agriculture. Such interaction and blending of farming practices is already taking place in both the developed and developing countries.

The status quo of different actors and interest groups promoting a specific set of farming practices (e.g. CSA, organic agriculture, CA, SRI etc.) and less acknowledgment of the other farming concepts and practices have contributed to the current impasse. If actors within the policy and scientific landscape are unable to move beyond such arguments, it becomes a challenge to discuss the specific tradeoffs and synergies of the pathways to sustainability. Moving beyond the current impasse will call for a consensus-oriented approach in the local, national, regional and global agricultural policy landscape and scientific arena. In a consensus-oriented approach, deliberations will focus on using evidence to shape agricultural sustainability polices. For example, the strong ecological focus of AEI could be made part of national policy agendas to bring SAI farming practices to greater sustainability. Similarly, the strong technological component (e.g. labour-saving technologies) of SAI can be used to modernise AEI practices. Such a fundamental shift and focus on the potential synergies will establish common ground and encourage resolution to achieve food security. Setting up knowledge platforms to discuss the different practices within AEI and SAI will be helpful for updating policy beliefs and achieving consensus.

The evidence from this study suggests that common grounds already exist due to the similarities and overlaps in terms of practices in the AEI and SAI pathways. A classic example relates to the role of mechanisation, which is often ignored in the debate. From Figure 1, it is somewhat clear that mechanisation (e.g. tillage or mechanical seeding) is an acceptable practice on both organic (AEI) and non-organic farms (SAI). Further innovations such as precision farming, water use technologies, digital farming and micro-dosing are used in different ways in both the AEI and SAI pathways depending on the agroecological region. As Wezel et al. (2015) suggest, the differences between the practices are sometimes rather blurred. In some cases, the practices are also mutually inclusive and very much depend on the agroecological, socio-economic and political factors, and institutional context of a location. For example, in some African countries where labour is an abundant resource, tractor services may not play a crucial role, but in many parts of the Global North, mechanisation plays a critical role in most production systems. Fertiliser application is another issue. In the Global South, where fertiliser use is very low (11.8kg/ha in 2002 and 16kg/ha in 2014) (World Bank & FAO, 2017) and some soils are extremely poor in (certain) nutrients (e.g., phosphorus), fertiliser is critical to sustainable farming (Morris, Kelly, Kopicki, Byerlee, 2007). The examples of mechanisation, irrigation and fertiliser largely suggest that sustainable agriculture cannot be universally defined, but depends on several factors.

To move forward, a more evidence-based and consensus-oriented approach is required. This has the potential to break new ground for scientific innovation in the area of organic and biological products, transformation of farmer-led innovations, and up-scaling and out-scaling of innovations. With the multidimensional aspects of issues involved and the complexity of farming systems, ultimately, decisions on the appropriate sustainable agriculture practices under AEI or SAI should be based on sustainability indicators (Mahon, Croute, Simmons, & Islam, 2017). The indicators can serve as core components to develop tracking tools that analyse progress towards achieving sustainable agriculture and the SDGs. As production decisions are made by individual farmers, strong policies and institutional incentives will be critical in achieving agricultural sustainability. This includes putting in place effective extension services to promote the adoption of AEI and SAI practices. As most AEI practices are labour intensive and most SAI practices are capital intensive, government incentives will be essential to the promotion of adoption of SAI and AEI. Government reforms on input subsidy programs in developing countries are also critical to deal with under- and over-use of subsidised inputs. Similar government incentives or subsidy programs will be critical for farmers to adopt practices such as conservation agriculture, CSA, system of rice intensification and organic agriculture practices. These policy options need to be implemented in a holistic manner in both the Global South and the North with the view of achieving a blended sustainability.

6 Conclusion

The needs to end hunger, achieve food security and improve nutrition, as well as restore and promote sustainable use of natural resources, have become increasingly important but contentious challenges among development partners, scientists and policy makers. The debate has centred on two sustainable agricultural approaches: AEI and SAI. The findings from this analysis suggest that the actors differ in their concept and vision of farming, as well as along the economic, ecological and social dimensions of agricultural sustainability. These fundamentally different perceptions make the question of which pathway to take to feed the growing population even more pertinent. At the same time, it is important to accept that there are synergies and tradeoffs between the AEI and SAI approaches. Acknowledgment of the tradeoffs implies that one pathway cannot be considered a panacea to achieving sustainable agriculture and food security. Rather, location-specific situations should determine the best set of practices by considering the strengths, opportunities, weaknesses, and threats of AEI and SAI and moving towards an integrated approach. Considering that the current impasse makes progress challenging, it is imperative to seek a more consensus-oriented approach among actors of the AEI and SAI pathways to sustainability. Setting up knowledge platforms will be critical for discussing and moving beyond the debate. Policy reforms in the area of input subsidy provision and institutional incentives to help farmers adopt appropriate AEI and SAI practices will be necessary to move beyond the debate towards a blended sustainability approach based on the synergies of AEI and SAI.

References

Altieri, M. (2002). Agroecology: The science of natural resource management for poor farmers in marginal environments. *Agriculture, Ecosystems & Environment 93*(1), 1-24.

Altieri, M., & Nicholls, C. (2005). *Agroecology and the search for a truly sustainable agriculture*. Mexico: United Nations Environment Programme. Retrieved from http://www.agroeco.org/doc/agroecology-engl-PNUMA.pdf

Altieri, M., & Toledo, V. M. (2011). The agroecological revolution in Latin America: Rescuing nature, ensuring food sovereignty and empowering peasants. *Journal of Peasant Studies, 38*(5), 587-612.

BASF. (2017) https://www.standort-ludwigshafen.basf.de/group/corporate/. Accessed on 16 February 2017.

BAYER. (2017) http://www.forwardfarming.com/concept. Accessed on 16 February 2017.

Bommarco, R., Kleijn, D., & Potts, S. G. (2013). Ecological intensification: Harnessing ecosystem services for food security. *Trends in Ecology & Evolution, 28*(4), 230-238. Campbell, B.M., Thornton, P., Zougmoré, R.,van Asten, P., & Lipper, L. (2014) Sustainable intensification: What is its role in climate smart agriculture? Current Opinion in Environmental Sustainability, 2014, 8: 39–43

Collins, E.D., & Chandrasekaran, K. (2012). A wolf in sheep’s clothing? An analysis of the sustainable intensification of agriculture. *Friends of the Earth International.* Retrieved from http://www.foei.org/wp-content/uploads/2013/12/Wolf-in-Sheeps-Clothing-for-web.pdf

Côte, F., Tomekpe, K., Staver, C., Depigny, S., Lescot, T., & Markham, R. (2010). Agro-ecological intensification in banana and plantain (Musa spp.): An approach to develop more sustainable cropping systems for both smallholder farmers and large-scale commercial producers. *IV International Symposium on Banana: International Conference on Banana and Plantain in Africa: Harnessing International 879* 457–463. doi:10.17660/ActaHortic.2010.879.50

CSA-guide-CCAFS (2017) https://csa.guide/csa/practices#article-9. Accessed on February 15, 2017

De Ataíde Cândido, G., Moura Nóbrega, M., Martins De Figueiredo, M.T., & Souto Maior, M.M. (2015). Sustainability assessment of agroecological production units: A comparative study of IDEA and MESMIS methods. *Ambiente & Sociedade, 18*(3), 99-120.

Doberman, A., & Nelson, R. (2013). Opportunities and solutions for sustainable food production. *Background paper for the High-Level Panel of Eminent Persons on the Post-2015 Development Agenda. Prepared by the co-chairs of the Sustainable Development Solutions Network Thematic Group on Sustainable Agriculture and Food Production.*

de la Rosa, D., Anaya-Romero, M., Diaz-Pereira, E., Heredia, N., & Shahbazi, F. (2009). Soil-specific agro-ecological strategies for sustainable land use – A case study by using MicroLEIS DSS in Sevilla Province (Spain). *Land Use Policy*, *26*(4), 1005-1065. doi: http://doi.org/10.1016/j.landusepol.2009.01.004

De Schutter, O. (2010). Report submitted by the Special Rapporteur on the right to food. *United Nations Human Rights Council. 16th session, agenda item, 3.*

Doré, T., Makowski, D., Malézieux, E., Munier-Jolain, N., Tchamitchian, M., & Tittonell, P. (2011). Facing up to the paradigm of ecological intensification in agronomy: Revisiting methods, concepts and knowledge. *European Journal of Agronomy*, *34*(4), 197-210. doi: http://doi.org/10.1016/j.eja.2011.02.006

Erjavec, K., & Erjavec, E. (2015). “Greening the CAP” – Just a fashionable justification? A discourse analysis of the 2014-2020 CAP reform documents. *Food Policy*, *51*, 53-62.

Fan, S., & Brzeska, J. (2016). Sustainable food security and nutrition: Demystifying conventional beliefs. *Global Food Security, 11*, 11-16. doi: http://dx.doi.org/10.1016/j.gfs.2016.03.005i

FAO (Food and Agriculture Organization). (2011). *Save and grow: A policymaker’s guide to the sustainable intensification of smallholder crop production*. Rome: Author. Retrieved from http://www.fao.org/3/a-i2215e.pdf

FAO. (2013). *Climate-smart agriculture*. Rome: Author.

FAO. (2015). Final report for the international symposium on agroecology for food security and nutrition. Retrieved from http://www.fao.org/3/a-i4327e.pdf

Feindt, P., & Kleinschmit, D. (2011). The BSE crisis in German newspapers: Reframing responsibility. *Science as Culture, 20*(2), 183-208.

Fischer J., Jabson, D., Butsic V., Chappell, M., Ekroos, J., Hanspach, J., Kuemmerle, T., Smith, H., & Wehrden, H. (2013). Land sparing versus land sharing: Moving forward. *Aspects of Applied Biology, 121*, 105-107.

Foley, J.A., Ramankutty, N., Brauman, K.A., Cassidy, E.S., Gerber, J.S., Johnston, M., . . . Zaks, D.P.M. (2011). Solutions for a cultivated planet. *Nature, 478*, 337-342. doi:10.1038/nature10452

Fonte, S.J., Vanek, S.J., Oyarzun, P., Parsa, S., Quintero, D.C., Rao, I.M., & Lavelle, P. (2012). Pathways to agroecological intensification of soil fertility managements by smallholder farmers in the Andean highlands. *Advances in Agronomy, 116*, 125-162.

Foran, T., Butler, J.R.A., Williams, L.J., Wanjura, W.J., Hall, A., Carter, L., & Carberry, P.S. (2014). Taking complexity in food systems seriously: An interdisciplinary analysis. *World Development, 61*, 85-101. doi:10.1016/j.worlddev.2014.03.023

Francis, C., Lieblein, G., Gliessman, S., Breland, T. A., Creamer, N., Harwood, R., . . . Poincelot, R. (2003). Agroecology: The ecology of food systems. *Journal of Sustainable Agriculture, 22*(3), 99-118. doi:10.1300/J064v22n03_10

Friedrich, T., Derpsch, R., & Kassam, A. (2012). Overview of the global spread of conservation Agriculture. *Field Actions Science Reports, Special Issue, 6.* Retrieved from: http://factsreports.revues.org/1941

Garnett, T., & Godfray, C. (2012). *Sustainable intensification in agriculture. Navigating a course through competing food system priorities*. Food Climate Research Network and the Oxford Martin Programme on the Future of Food, University of Oxford, UK. Retrieved from http://www.fcrn.org.uk/sites/default/files/SI_report_final.pdf

Gliessman, S. (2014). Is there sustainability in “Sustainable Intensification”? *Agroecology and Sustainable Food Systems, 38*(9), 993-994. doi:10.1080/21683565.2014.939800

Gliessman, S. (2016). Transforming food systems with agroecology. *Agroecology and Sustainable Food Systems, 40*(3), 187-189. doi:10.1080/21683565.2015.1130765

Godfray, C. (2015). The debate over sustainable intensification. *Food Security, 7*, 199-208.

Godfray, H.C., Crute, I.R., Haddad, L., Lawrence, D., Muir, J.F., Nisbett, N., . . . Whiteley, R. (2010). The future of the global food system. *Phil. Trans. R. Soc. B, 365*(1554), 2769-2777. doi:10.1098/rstb.2010.0180

Grote, U. (2014). Can we improve global food security? A socio-economic and political perspective. *Food Security, 6*(2), 187-200. doi:10.1007/s12571-013-0321-5

Hajer, M. (2006). Doing discourse analysis: Coalitions, practices, meaning. In V.d.B.T. Metze (Ed.), *Words matter in policy and planning: Discourse theory and methods in the Social Sciences* (65-77). Utrecht.

Hayati D.Z. Ranjbar, and E. Karami (2010): Measuring agricultural sustainability. In E. Lichtfouse (Ed.), *Biodiversity, biofuels, agroforestry and conservation agriculture* (73-100), Sustainable Agriculture Reviews 5, Springer.

Hobbs, P.R., Sayre, K., & Gupta, R. (2008). The role of conservation agriculture in sustainable agriculture. *Phil. Trans. R. Soc. B,363*(1491), 543-555. doi:10.1098/rstb.2007.2169

Ikerd, J.E. (1993). The need for a systems approach to sustainable agriculture. *Agriculture, Ecosystems & Environment, 46*(1), 147-160.

IRR (International Rice Research Institute). (2017) http://irri.org/news/hot-topics/system-of-rice-intensification-sri. Accessed on March 28, 2017.

Kaczan, D., Arslan, A., & Lipper, L. (2013). *Climate-smart agriculture: A review of current practice of agroforestry and conservation agriculture in Malawi and Zambia.* Rome: FAO.

Karamura, E.B., Jogo, W., Rietveld, A., Ochola, D., Staver, C., Tinzaara, W., . . . Weise, S. (2013). Effectiveness of agro-ecological intensification practices in managing pests in smallholder banana systems in East and Central Africa. *Acta Hort. (ISHS)*(986), 119-126.

Kassam, A., Friedrich, T., Shaxson, F., & Pretty, J. (2009). The spread of conservation agriculture: Justification, sustainability and uptake. *International Journal of Agricultural Sustainability, 7*(4), 292-320. doi:10.3763/ijas.2009.0477

Lipper, L., Thornton, P., Campbell, B.M., Baedeker, T., Braimoh, A., Bwalya, M., . . . Torquebiau, E.F. (2014). Climate-smart agriculture for food security. *Nature Climate Change*, *4*(12), 1068-1072. doi:10.1038/nclimate2437

Mahon, N., Croute, I., Simmons, E., & Islam, M.M. (2017). Sustainable intensification – “oxymoron” or “third-way”? A systematic review. *Ecological Indicators, 74,* 73–97.

Matson, P.A., Parton, W.J., Power, A.G., & Swift, M.J. (1997). Agricultural intensification and ecosystem properties. *Science, 277*(5325), 504-509.

McCune, N.M., González, Y.R., Alcántara, E.A., Martínez, O.F., Fundora, C.O., Arzola, N.C., Hernández, F.G. (2011). Global questions, local answers: Soil management and sustainable intensification in diverse socioeconomic contexts of Cuba. *Journal of Sustainable Agriculture, 35*(6), 650-670. doi:10.1080/10440046.2011.586595

McIntyre, B.D., Herren, H.R., Wakhungu, J., & Watson, R.T. (2009). *Agriculture at a crossroads. Synthesis report and global summary for decision makers.* Washington, DC: IAASTD. Retrieved from http://apps.unep.org/redirect.php?file=/publications/pmtdocuments/-Agriculture%20at%20a%20crossroads%20-%20Synthesis%20report-2009Agriculture_at_Crossroads_Synthesis_Report.pdf

Milder, J.C., Garbach, K., DeClerck, F.A.J., Driscoll, L., & Montenegro, M. (2012). *An assessment of the multi-functionality of agroecological intensification*. Retrieved from https://agriknowledge.org/downloads/kh04dp73w

Mockshell, J., & Birner, R. (2016) Agricultural development policy debates: Who has the better story? In J. Mockshell (Ed.), *Two worlds in agricultural policy making in Africa? Case studies from Ghana, Kenya, Senegal and Uganda.* Dissertation submitted to the University of Hohenheim, Germany.

Mockshell, J., & Birner, R. (2015). Donors and domestic policy makers: Two worlds in agricultural policy-making? *Food Policy, 55,* 1-14.

Montpellier Panel. (2013). *Sustainable intensification: A new paradigm for African agriculture.* Retrieved from http://ag4impact.org/wp-content/uploads/2013/04/MP_0176_Report_Redesign_2016.pdf

Morris, M., Kelly, V.A., Kopicki, R., & Byerlee. D. (2007). Fertilizer use in African agriculture: Lessons learned and good practice guidelines. Washington, DC: World Bank.

Nelson, G.C., Rosegrant, M., Koo, J., Robertson, R., Sulser, T., Zhu, T., . . . Lee, D. (2009). *Climate change. impact on agriculture and costs of adaptation.* Food Policy Report, 21. Washington, D.C.: International Food Policy Research Institute. Retrieved from http://www.fao.org/fileadmin/user_upload/rome2007/docs/Impact_on_Agriculture_and_Costs_of_Adaptation.pdf

Nyantakyi-Frimpong, H., Kangmennaag, J., Bezner, R.K., Luginaah, I., Dakishoni, L., Lupafya, E., Shumba, L., Katundu, M., (2016) Agroecology and healthy food systems in semi-humid tropical Africa: Participatory research with vulnerable farming households in Malawi. Acta Trop. 30817-8 10.1016/j.actatropica.2016.10.022

Ochola, D., Jogo, W., Ocimati, W., Rietveld, A., Tinzaara, W., Karamura, D.A., & Karamura, E.B. (2013). Farmers’ awareness and perceived benefits of agro-ecological intensification practices in banana systems in Uganda. *African Journal of Biotechnology, 12*(29), 4603-4613. doi:10.5897/ajb12.2868

Parmentier, S. (2014). Scaling Up Agroecological Approaches: What, Why and How? Belgium: Oxfam-Solidarity. Retrieved from:http://www.fao.org/fileadmin/templates/agphome/scpi/Agroecology/Agroecology_Scaling-up_agroecology_what_why_and_how_-OxfamSol-FINAL.pdf

Pingali, P.L., & Gerpacio, R.V. (1997). Living with reduced insecticide use for tropical rice in Asia. *Food Policy, 22*(2), 107-118.

Pretty, J. (1997). Sustainable intensification of agricultural. *Natural Resources Forum, 21*(4), 247-256.

Pretty, J. (2008). Agricultural sustainability: Concepts, principles and evidence. *Phil. Trans. R. Soc. B, 363*(1491), 447-465. doi:10.1098/rstb.2007.2163

Pretty, J., Toulmin, C., & Williams, S. (2011). Sustainable intensification in African agriculture. *International Journal of Agricultural Sustainability, 9*(1), 5-24. doi:10.3763/ijas.2010.0583

Pretty, J.N., Nobel, A.D., Bossio, D., Dixon, J., Hine, R.E., Penning De Vries, F.W.T, & Morison, J.I.L. (2006) Resource conserving agriculture increases yields in developing countries. *Environmental Science and Technology, 40*(4), 1114-119.

Raintree, J.B. (1986). Agroforestry pathways for intensification of shifting cultivation. *Agroforestry Systems, 4*(1), 39-54.

Ray D.K., Mueller, N.D., West, P.C., & Foley, J.A. (2013). Yield trends are insufficient to double global crop production by 2050. *PLoS ONE, 8*(6).

Reardon, T., Barrett, C., Kelly, V., & Savadogo, K. (1999). Policy reforms and sustainable agricultural intensification in Africa. *Development policy review, 17*(4), 375-395.

Rolando, J.L., Turin, C., Ramírez, D.A., Mares, V., Monerris, J., & Quiroz, R. (2017). Key ecosystem services and ecological intensification of agriculture in the tropical high-Andean Puna as affected by land-use and climate changes. *Agriculture, Ecosystems and Environment, 236,* 221-236.

SRI International Network and Resource Canter (2017). http://sri.ciifad.cornell.edu/aboutsri/methods/index.html. Accessed on 28 March, 2017.

Scialabba, N.E.-H., & Müller-Lindenlauf, M. (2010). Organic agriculture and climate change. *Renewable agriculture and food systems, 25*(02), 158-169.

Steinfeld, H. (2006). *Livestock's long shadow: Environmental issues and options*. Rome: FAO.

Struik, P.C., & Kuyper, T.W. (2014). Sustainable intensification to feed the world: Concepts, technologies and trade-offs. *Current Opinion in Environmental Sustainability, 8*, vi–viii.

Struik, P.C., Kuyper, T.W., Brussaard, L., & Leeuwis, C. (2014). Deconstructing and unpacking scientific controversies in intensification and sustainability: Why the tensions in concepts and values? *Current Opinion in Environmental Sustainability, 8*, 80-88. doi:10.1016/j.cosust.2014.10.002

Sumberg, J. (2002). The logic of fodder legumes in Africa. *Food Policy, 27*(3), 285-300.

Tilman, D. (1999). Global environmental impacts of agricultural expansion: The need for sustainable and efficient practices. *Proceedings of the National Academy of Sciences, 96*(11), 5995–6000.

Tilman, D., Balzer, C., Hill, J., & Befort, B. L. (2011). Global food demand and the sustainable intensification of agriculture. *Proceedings of the National Academy of Sciences, 108*(50), 20260-20264.

Tittonell, P. (2014). Ecological intensification of agriculture-sustainable by nature. *Current Opinion in Environmental Sustainability, 8*, 53-61. doi:10.1016/j.cosust.2014.08.006

Tomich, T.P., Brodt, S., Ferris, H., Galt, R., Horwath, W.R., Kebreab, E., . . . Yang, L. (2011). Agroecology: A review from a global-change perspective. *Annual Review of Environment and Resources, 36*(1), 193-222. doi:10.1146/annurev-environ-012110-121302

UN (United Nations). (2015). *Transforming our world: The 2030 Agenda for sustainable development*. Retrieved from https://sustainabledevelopment.un.org/post2015/transformingourworld

Vanlauwe, B., Coyne, D., Gockowski, J., Hauser, S., Huising, J., Masso, C., . . . Van Asten, P. (2014). Sustainable intensification and the African smallholder farmer. *Current Opinion in Environmental Sustainability, 8*, 15-22. doi:10.1016/j.cosust.2014.06.001

van Noordwijk, M., Hoang, M.H., Neufeldt, H., Öborn, I., & Yatich, T. (2011). *How trees and people can co-adapt to climate change*. Nairobi: World Agroforestry Centre (ICRAF). Retrieved from http://www.asb.cgiar.org/PDFwebdocs/PDFwebdocs/How%20trees%20and%20people%20can%20co-adapt%20to%20climate%20change.pdf

Verbung, P.H., Mertz, O., Erb, K.H., Haberl, H. Wu, W. Land system change and food security: towards multi-scale land system solutions. 5(5) 494-502.

Vignola, R., Harvey, C.A., Bautista-Solis, P., Avelino, J., Rapidel, B., Donatti, C., & Martinez, R. (2015). Ecosystem-based adaptation for smallholder farmers: Definitions, opportunities and constraints. *Agriculture, Ecosystems and Environment, 211*, 126-132. doi:10.1016/j.agee.2015.05.013

von Braun, J., Fan, S., Meinzen-Dick, R., Rosegrant, M., & Nin Pratt, A. (2008). *International agricultural research for food security, poverty reduction, and the environment: What to expect from scaling up CGIAR investments and "best bet" programs (No. 594-2016-39951).* Washington, DC: International Food Policy Research Institute. Retrieved from http://ageconsearch.umn.edu/record/46016/files/oc58.pdf

Wezel, A., Soboksa, G., McClelland, S., Delespesse, F., & Boissau, A. (2015). The blurred boundaries of ecological, sustainable, and agroecological intensification: A review. *Agronomy for Sustainable Development, 35*(4). doi:10.1007/s13593-015-0333-y

Wezel, A., & Soldat, V. (2009). A quantitative and qualitative historical analysis of the scientific discipline of agroecology. *International Journal of Agricultural Sustainability, 7*(1), 3-18. doi:10.3763/ijas.2009.0400

Wheeler, T., & von Braun, J. (2013). Climate change impacts on global food security. *Science, 341*(6145), 508-513. doi:10.1126/science.1239402

World Bank. (2003). *World* Development *Report 2003: Sustainable development in a dynamic world: Transforming institutions, growth, and quality of life.* Retrieved from https://openknowledge.worldbank.org/handle/10986/5985

World Bank. (2008). *World Development Report 2008: Agriculture for development*. Washington, DC: Author.

Yunlong, C., & Smit, B. (1994). Sustainability in Chinese agriculture: Challenge and hope. *Agriculture, Ecosystems & Environment, 49*(3), 279-288.

Zimmerer, K.S., Carney, J.A., & Vanek, S.V. (2015). Sustainable smallholder intensification in global change? Pivotal spatial interactions, gendered livelihoods, and agrobiodiversity. *Current Opinion in Environmental Sustainability, 14*, 49-60. doi:http://dx.doi.org/10.1016/j.cosust.2015.03.004

Appendix

Table A1: Differences between agroecological intensification and sustainable agricultural intensification

Indicators	**Agroecological intensification (AEI)**	**Sustainable agricultural intensification (SAI)**
Actors (emphasis on organisations)	NGOs[8], academic, farmer organisations, environmental NGOs: Friends of the Earth International[9]	Agrochemical and fertiliser industry (e.g. Bayer, BASF)[10],[11], academic, FAO, CGIAR, World Economic Forum, Montpellier Panel, USAID's Feed the Future, IFDC, Sustainable Development Solutions Network[12], Alliance for a Green Revolution for Africa, bilateral donors and development banks in Asia, Bill and Melinda Gates Foundation
Concept/ theoretical orientation		- generally loosely defined; almost any model or technology can be labelled under it[13]
	- provide basic ecological principles for how to study, design and manage agro-ecosystems that are both productive and natural resource conserving, and that are also culturally sensitive, socially just and economically viable[14] - increase agricultural outputs (food, fibre, agrofuels and environmental services) while reducing the use and the need for external inputs (agrochemicals, fuel, and plastic), while capitalising on ecological processes that support and regulate primary productivity in agroecosystems[15] - manage service-providing organisms that make a quantifiable direct or indirect contribution to agricultural production[16] - use biological regulation to manage agroecosystems, at field, farm and landscape scales	- original aim: increase agricultural productivity while simultaneously protecting the natural resource base; low-input (though not zero-input) agriculture can be highly productive, founded on local knowledge and full farmer participation in technology development[17]
	- increase agricultural output by capitalising on ecological processes in agroecosystems - take advantage of beneficial on-farm interactions to reduce off-farm input	- pay attention to environmental (and other forms of) sustainability, as well as to increased production[19]

8 Altieri, 1993
9 Tittonell, 2014
10 BASF, 2017
11 BAYER, 2017
12 Tittonell, 2014
13 Tittonel, 2014
14 Altieri, 2002
15 Tittonell & Giller, 2013
16 Bommarco et al., 2013
17 Struik & Kuyper, 2014
19 Struik & Kuyper, 2014,

	use and improve the efficiency of farming systems[18]	
	- aim to mimic nature/functioning local ecosystems[20,21,22]	
	- holistic study of agroecosystems, including all environmental and human elements[23,] - emphasis on social, economic, and political dynamics shaping agricultural production systems[24]	- focus on resource intensification and resource use efficiency,[25,26,27,28] - differences in focus: on production or broader perception - economic interests dominate decision making - meets the needs of the present generation without comprising the ability of future generations to meet their needs
Vision	- sustainable alternatives to (the hegemonic style of) conventional and agro-industrial agriculture[29] - replace the reliance on external inputs by re-establishing ecosystem services generated in the soil and the landscape surrounding the cultivated field, while maintaining high, stable productivity levels	- alternative to conventional intensification[30]
	- sustainability of agricultural systems[31] - more sustainable farming styles	- to sustainably intensify agriculture[32]
	- food security (production increase, accessibility, accessible to the poor, cost-effectiveness, environmental sustainability) - intensification of production systems to satisfy the anticipated increase in food demand while meeting acceptable standards of environmental quality	- food and nutritional security, reduce overconsumption, reduce food waste, enhance diets[33] - based on the belief that increased food production is directly related to food security and poverty eradication - adhere to acceptable standards of animal welfare[34] - support rural economies and sustainable development, reduce rural poverty, integrate farmers into overall economy[35]

18 Altieri, 2002

20 Nyantakyi-Frimpong et al., 2016

21 Altieri, 2002

22 Struik & Kuyper, 2014

23 Altieri, 2002

24 Altieri et al. 2012

25 Gliessman, 2014

26 Tittonell, 2014

27 Struik et al., 2014

28 Struik & Kuyper, 2014

29 Struik & Kuyper, 2014

30 Struik & Kuyper, 2014

31 Altieri, 2002

32 Struik & Kuyper, 2014

33 Campbell, Thornton, Zougmoré, van Asten, & Lipper, 2014

34 Campbell et al., 2014

35 Campbell et al., 2014

		- reduce (negative) environmental impacts of agriculture - conserve forest - resilience to shocks and stresses, including climate change
	- maintain and enhance ecosystem functions[36]	- maintain and enhance ecosystem functions[37]
	- holistic approach to rural development	- respond to persistent societal challenge of how to feed, house and care for growing population
	- pro-poor focus	

36 Tittonell, 2014

37 Tittonell, 2014

Indicators	Agroecological intensification (AEI)	Sustainable agricultural intensification (SAI)
Economic dimension		
Efficiency	- land-use efficiency (yield) - raise total production through diversification of farming systems[38]	- land equivalent ratios - increasing output/food production from existing farmland[39,40]
	- yield gap/yield potential or water-limited potential	- farm or landscape productivity gap/possibility frontier
	- efficiency as a ratio (output per unit input)	- efficiency as an emerging property (matrix)
	- adoption of promoted multi-functional technologies (e.g. cover crops, green manures, intercropping, agroforestry, crop-livestock mixtures), usually means favourable changes in various components of the farming systems at the same time[41]	
	- over time more stable levels of total production per unit area than high-input systems, produce economically favourable rates of return	
Independence (e.g. seed system)	- currently there are no powerful or well-financed interests supporting agroecology as there are for biotechnology	- large-scale investors in SSA agriculture may provide a pathway to intensified agricultural production, (e.g. by contract farming models organised around “nucleus farms”), but the discourse around “land grabbing” has raised concerns in relation to equity and sustainability impacts on rural livelihoods - government investments and policy frameworks are crucial, including facilitating private sector engagement and smart subsidy programs[42] - powerful interests finance biotechnology research
	- agroecological practices that improve soil fertility can loosen the growing constraint of water supply - no need to purchase commercial fertiliser or seeds (e.g. own seed sharing networks) [43]	- dependence on commercial seed system
Viability	- agroecological methods require skill and knowledge, which can be acquired more easily than land or capital by the poor	- competing and conflicting interests persistently hamper sustainable supply chain management - low margins: not easy for individual actors to take action for change

38 Altieri, 2002
39 Campbell et al., 2014
40 Pretty et al., 2011
41 Altieri, 2002
42 Vanlauwe, Coyne, Gockowski, Hauser, Huising, Masso, Nziguheba, Schut, & Van Asten, 2014
43 Nyantakyi-Frimpong et al., 2016

	- does not offer quick fixes: serious investment in this type of research requires long-term commitment[44] - sustainable agricultural systems can be economically, environmentally and socially viable, and contribute positively to local livelihoods, however, without appropriate policy support, they are likely to remain localised in extent[45] - universal applicability required [46] - appropriate technology adapted as a result of farmers' experimentation[47] - strategic partnerships (farmer-external agencies, partnerships between agencies)[48] - policy and market options[49]	- may be detrimental to farming households, especially when family labour, farm size, and diversified farming strategies pose eminent challenges for farm intensification
Social dimension		
Ethics and human development	- causes less stress[50] - increases incomes: addresses labour and soil fertility constraints, access for clinical care in HIV-affected families due to increase in farmer income[51] - health: wellbeing and food security (incl. dietary diversity)[52] - provides climate change relevant ecosystem services: carbon sequestration, energy use efficiency, soil water holding capacity, resilience to drought, hurricanes and heavy rainfall[53] - contributes positively to local livelihoods through increased incomes[54]	- contributes to climate change adaptation and mitigation through sustainable intensification of livestock production systems and increased resource use efficiency[55] - increased farm incomes contribute to increased global food and nutrition security[56] - initiatives and investments to intensify agricultural production can expose smallholder farmers to increased risks, a large proportion of this community is considered highly vulnerable to production risks, which is further aggravated by climate change - the discourse around "land grabbing" by large-scale investors in SSA agriculture has raised concerns in relation to equity and sustainability impacts on rural livelihoods

44 Tittonell, 2014
45 Altieri, 2002
46 Altieri, 2002
47 Altieri, 2002
48 Altieri, 2002
49 Altieri, 2002
50 Nyantakyi-Frimpong et al., 2016
51 Nyantakyi-Frimpong et al., 2016
52 Nyantakyi-Frimpong et al., 2016
53 Tittonell, 2014
54 Altieri, 2002
55 Campbell, et. al., 2014
56 Campbell, et. al., 2014

		- not likely to improve food security if it continues to focus narrowly on food production ahead of other equally or more important variables that influence food security (e.g. food accessibility)[57]
Livelihood support	- reduces labour burden of HIV-affected households[58] - reduces need to purchase costly artificial fertilisers[59] - increases incomes[60]	- increases incomes[61]
Knowledge generation	- ecological management of natural resources through a collective social action of participatory nature - participatory approach - prominent role of locally available resources and indigenous knowledge - farmers are not mere adopters of technologies but also generate locally adapted knowledge and technologies [62,63] - knowledge/information sharing (e.g. seed banks)[,64] - local institutional capacity[65] - diversified sources of knowledge and the methods used to compile, organise and analyse such knowledge - embeds scientific knowledge into local innovation systems	- knowledge intensive and depends on expert knowledge
Ecological dimension		
Products and territory quality	- improves soils and increases crop yield[66] - recycles biomass and balances nutrient flow and availability[67] - minimises losses of solar radiation, air, water and nutrients by way of microclimate management, water harvesting and soil cover[68] - enhances beneficial biological interactions and synergisms among	- enhances soil quality; generates vital regulates services of buffering, filtering and moderating the hydrological cycle improves soil biodiversity - land sparing effects - increased production can trigger increased consumption as a result of lower prices, and improved agricultural

57 Gliessman, 2014

58 Nyantakyi-Frimpong et al., 2016

59 Nyantakyi-Frimpong et al., 2016

60 Nyantakyi-Frimpong et al., 2016

61 Campbell, et al., 2014

62 Nyantakyi-Frimpong et al., 2016

63 Tittonell, 2014

64 Nyantakyi-Frimpong et al., 2016

65 Altieri, 2002

66 Nyantakyi-Frimpong et al., 2016

67 Altieri, 2002

68 Altieri, 2002

	agrobiodiversity components, resulting in the promotion of key ecological processes and services[69] - provides ecosystem services of support and regulation by managing both in-field and off-field diversity[70] - soil is not disturbed by ploughing; additionally, it is kept protected by some vegetative cover, living or dead - land husbandry as an "an ecology of disciplines" - renews and conserves the biologically-moderated spaces in the soil in the root-zone rather than on the solid soil-particles themselves.	opportunities may attract new activities on "spared" land[71] - often water availability for irrigation is limited in SSA[72]
Spatial arrangement	Mixed cropping	Monoculture
	- assembles crops, animals, trees, soils and other factors in spatial/temporal diversified schemes[7374] - spatial and chronological arrangement of the plants in the natural ecosystem are used to design a crop system analogous to the natural system - reduces the reliance on subsistence cereal production, integration with livestock enterprises, greater crop diversification, and agroforestry systems that provide higher economic value and foster soil conservation	- involves either land sparing or land sharing
Agricultural practices	- favours natural processes and bio-logical interactions that optimise synergies so that diversified farms are able to sponsor their own soil fertility, crop protection and productivity - legume relay and intercropping, e.g. adding pigeon peas, groundnuts, and soya beans to maize cropping systems, or rotating legume crops with maize[75]	- food demand needs to be met using only existing agricultural land, since opening new land for farming leads to degradation - agriculture carries major environmental costs[83] - fertilisers as the natural link between intensification and sustainability[84]

69 Altieri, 2002

70 Tittonell, 2014

71 Verburg et al., 2013

72 Verburg et al., 2013

73 Altieri, 2002

74 Tittonell, 2014

75 Nyantakyi-Frimpong et al., 2016

83 Campbell, et al., 2014

84 Tittonell, 2014

	- buries legume residue to strengthen soil structure and fertility[76] - customises agricultural technologies to suit local needs and circumstances[77] - assembles crops, animals, trees, soils and other factors in spatial/temporal diversified schemes[78] - spatial and chronological arrangement of the plants in the natural ecosystem are used to design a crop system analogous to the natural system[79][80] - direct seeding and use of mulch - soil is not disturbed by ploughing; additionally, it is kept protected by some vegetative cover, living or dead - mixed cropping, conservation tillage, diversification of the crop rotation, or the use of cover crops - explicitly implies reducing external inputs (fertilisers, pesticides, fuels) and increasing the use of ecosystem services[81] - practices aim to mimic nature[82] - no contradiction in combining agro-ecological and biotechnological approaches to improve performance in the field; agroecological approaches to agricultural development do not make genetic improvements unimportant or unnecessary	- combines the use of new and improved varieties and new agronomic-agroecological management[85] - very often involves more complex mixes of domesticated plant and animal species and associated management techniques, requiring greater skills and knowledge by farmers[86] - FAO: focuses on conservation agriculture – minimal tillage, use of mulch and cover crops, perennial agriculture, and for developing countries possibly also mineral fertiliser[87]

76 Nyantakyi-Frimpong et al., 2016

77 Altieri, 2002

78 Altieri, 2002

79 Altieri, 2002

80 Tittonell, 2014

81 Struik & Kuyper, 2014

82 Nyantakyi-Frimpong et al., 2016

85 Pretty et al., 2011

86 Pretty et al., 2011

87 Struik and Kuyper, 2014

Indicators	Agroecological intensification (AEI)	Sustainable agricultural intensification (SAI)
Proponents of AEI and SAI		classic regulatory government intervention has proven to support sustainable developments
Opponents of AEI and SAI		grass-root organisations and environmental movements around the world are weary of the term sustainable intensification which they often see as a window-dressing, green-washing strategy to justify any form of intensification
	agroecology is backwards and cannot provide enough yield to feed the world	food production is removed from social and ecological space
	"do nothing approach" and low external input use	described as "business as usual", high external input use
	agricultural systems that most resemble (mimic) nature are traditional agricultural systems, which often are relatively low-intensity and unproductive[88]	remains contested, that intensification improves the efficiency with which resources are utilised[89]
Other components or names	organic agriculture, ecological agriculture, alternative agriculture, conservation agriculture, landscape or ecosystem approach, agroforestry/ evergreen agriculture[90]	CSA sustainable supply chain management

88 Struik & Kuyper, 2014

89 Campbell, et al., 2014

90 Tittonell, 2014

Publications of the German Development Institute/ Deutsches Institut für Entwicklungspolitik (DIE)

Studies

94 Altenburg, Tilman, Cecilia Fischer, Kerstin Huck, Anna Kruip, Sören Müller, & Stefanie Sörensen. (2017). *Managing coastal ecosystems in the Philippines: What Cash for Work programmes can contribute* (108 pp.). ISBN 978-3-96021-033-7.

93 Cottrell, Jacqueline, Kai Schlegelmilch, Matthias Runkel, & Alexander Mahler. (2016). *Environmental tax reform in developing, emerging and transition economies* (113 pp.). ISBN 978-3-96021-017-7.

92 Berger, Axel, Dominique Bruhn, Andrea Bender, Julia Friesen, Katharina Kick, Felix Kullmann, Robert Roßner, & Svenja Weyrauch. (2016). *Deep preferential trade agreements and upgrading in global value chains: The case of Vietnam* (119 pp.). ISBN 978-3-96021-016-0.

[Price: EUR 10.00; publications may be ordered from the DIE or through bookshops.]

Discussion Papers

15/2017 Beierl, Stefan, Francesco Burchi, & Christoph Strupat. *Economic empowerment pilot project in Malawi: Qualitative survey report* (35 pp.). ISBN 978-3-96021-037-5.

14/2017 Ali, Murad. *Implementing the 2030 Agenda in Pakistan: the critical role of an enabling environment in the mobilisation of domestic and external resources* (37 pp). ISBN 978-3-96021-036-8.

13/2017 Kappel, Robert, Birte Pfeiffer, & Helmut Reisen. *Compact with Africa: Fostering private long-term investment in Africa* (50 pp.). ISBN 978-3-96021-035-1.

12/2017 Serdeczny, Olivia. *What does it mean to "address displacement" under the UNFCCC? An analysis of the negotiations process and the role of research* (40 pp.). ISBN 978-3-96021-034-4.

11/2017 Houdret, Annabelle, & Astrid Harnisch. *Decentralisation in Morocco: The current reform and its possible contribution to political liberalisation* (39 pp.). ISBN 978-3-96021-032-0.

10/2017 Mahn Jones, Timo. *Accountability for development cooperation under the 2030 Agenda* (41 pp.). ISBN 978-3-96021-031-3.

9/2017 Camacho, Luis A., & Merle Kreibaum. *Cash transfers, food security and resilience in fragile contexts: General evidence and the German experience* (20 pp.) ISBN 978-3-96021-029-0.

8/2017 Weigel, Moritz, & Alexander Demissie. *A new climate trilateralism? Opportunities for cooperation between the EU, China and African countries on addressing climate change* (28 pp). ISBN 978-3-96021-030-6.

7/2017 Öhler, Hannes. *A micro-level analysis of the effects of aid fragmentation and aid alignment* (24 pp.). ISBN 978-3-96021-028-3.

[Price: EUR 6.00; publications may be ordered from the DIE or through bookshops.]

For a complete list of DIE publications:
www.die-gdi.de