Sustainable Intensification: Definitions, Principles and Boundaries

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1. Introduction

Core Theme 2 of the strategic research agenda of the Agriculture, Food Security and Climate Change (FACCE) Joint Programming Initiative (JPI) has as its focus the 'Environmentally Sustainable Intensification of Agricultural Systems'. Aiming for alignment, the creation of synergy and research uptake within this Core Theme, a Knowledge Network on Sustainable Intensification (KNSI) is currently, as stipulated in the FACCE-JPI strategy, being developed.

Attempts at defining the scope and activities of KNSI activities have revealed a need for a common understanding of sustainable intensification's (SI) definitions, principles and boundaries, in support of a practical framework for implementation of SI approaches. On this background, the ambition of this paper is to define and delimit the SI concept. The endeavour, initially, entails a review of the concept's history and usage. It then moves on to an analysis of the concept's relation to both contrasting and associated research agendas, before pointing to key operational aspects.

2. History and Usage of the Sustainable Intensification Concept

First appearing in publications by prominent rural development scholars in the 1990s (see e.g. Conway 1997, Pretty 1997), the frequency of the use of the SI concept in scientific works and in policy reports has risen dramatically in the past two decades (see Gunton et al. 2016, Wezel et al. 2015 for overviews). Reaching unprecedented popularity in recent years, SI is central to United Nations Sustainable Development Goal 2, suggesting that it will remain on policy agendas for a while (Gunton et al.).

The SI concept arose as a reaction to the perceived lack of social and environmental sustainability (pesticides, chemical fertilisers, machinery, land degradation, physical area expansion etc.) of the high external input paradigm of the green revolution and of industrial agriculture (Conway 1997, Pretty 1997). In 1997, Pretty, for instance, saw SI as a means to achieve substantial growth in currently unimproved or degraded areas while at the same time protecting or even regenerating natural resources. The idea that agricultural intensification – an increase in output per unit of land

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– could be achieved without harming the environment, represented a paradigm shift not only in relation to high external input agriculture, but also in relation to environmentalist perspectives: Before the late 1990s, intensification was synonymous with agriculture that “inevitably caused harm while producing food” (Pretty & Bharucha 2014:1578). With the climate agenda gaining momentum in the 2000s, the concept gradually became associated with nexus (water, energy, climate etc.) perspectives (see e.g. Hoff 2011), and the reduction of agriculture’s climate gas emissions and increased food production as the key rationales for SI.

The most widely (and broadest) SI definition currently used (according to Wezel et al. 2015) also stems from Pretty:

“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” (2008:451).

The Food and Agriculture Organisation (FAO 2011), a couple of years later, offered another widely cited definition:

“Producing more from the same area of land while conserving resources, reducing negative impacts on the environment and enhancing natural capital and the flow of ecosystem services” (FAO 2011:2).

The Rise Foundation, in 2014, offered the following definition:

“Sustainable Intensification means simultaneously improving the productivity and environmental management of agricultural land” (Rise 2014:7).

Indicative of SI’s association with total factor productivity (institutions, innovation, systems) and the resource efficiency of agriculture, rather than physical area expansion, the latter publication also contributed to the popularity of the notion of “more knowledge per hectare” (2014: 7) as shorthand for sustainable intensification.

3. Principles of SI: Many Things to Many People

As the evolvement of SI and its definitions suggest, SI emphasises wide ‘drivers’, priorities and goals in comparison with purely productivity oriented agriculture (see Pretty & Bharucha 2014). Its principles, as evident from the definitions, can be narrowed down to sustainability (eliminating harm/reducing negative impacts/improving environmental management of land), resource efficiency, limited conversion of land and, at the levels of policy and research, a focus on total factor productivity. The notion of yield gap closure, i.e. closing (or rather reducing) the gap between current yields and yield potential on existing cropland, while avoiding negative environmental effects (see van Ittersum et al. 2016), is central to this thinking. So is the closing of nutrient loops, associated water-wise agricultural production, transformation of agriculture from carbon source to carbon sink, and (bio)diversity, (see Rockström et al. 2016).

The dramatic rise in the popularity of the SI concept, it appears, has been accompanied by an increased breadth of meaning, to the point where, paraphrasing Narayan and Pritchett (1997), *sustainable intensification, while not all things to all people, is many things to many people*[3]. In this vein, Wezel et al. argue that SI remains "more an aspiration to increase yields without environmental damage – rather than a clear set of specific practices" (2015:1288).

As argued by Gunton et al. (2016), the increased breadth of meaning of SI has been accompanied by an increasingly ambiguous understanding of the concept, and a feeling among many agricultural experts that SI does not hold much that is new in terms of agricultural practices. These circumstances – considering that the SI concept keeps gaining momentum in scientific and in grey literature – confirms the need for clarification of the concept.

4. SI and Contrasting Approaches in a Political Economy Perspective

Sumberg et al. (2013) point out that agricultural research and the agricultural approaches that they underpin are contested issues; agricultural pathways compete and should be understood in terms of political economy, i.e. in terms of their economic and political premises and the interests that they serve. A political economy analytical point of departure serves to illuminate why certain approaches and discourses on agriculture dominate at certain points in time. In turn, this allows critical examination of competing approaches, with analysis of their framing, divergences and overlaps leading to clearer understandings of boundaries. SI is indeed a contested approach that interfaces with a number of context-specific policy priorities that include biodiversity and land use, animal welfare, human nutrition, rural economies and sustainability vs production concerns (Garnett et al. 2014).

It can be argued that the current dominance of the SI concept is due to its location within the dominant *food first* narrative. In this narrative agriculture is seen as the single largest global driver of environmental change (Rockström et al. 2016), in a world that needs to 'feed 9+ billion by 2050', with technology as a major factor in achieving this goal (see Royal Academy of Engineering 2016). Within this double, triple and sometimes even quadruple *squeeze* thinking (see Rockström & Karlberg 2010)[4], agricultural production is closely associated with the global challenges of population growth and economic growth as factors that increase demand for food, feed and other bio-based products. Climate change will to lead to considerable variation in conditions for agriculture and subsequent food supply vulnerability across the globe: Geographically, socially and economically contextualised, SI is seen as one means to address the challenges.

The *food first* and *feed the 9+ billion* narratives contrast with what we may call a 'distributionism' narrative. Promoted by environmental and agroecological movements, the world, in this competing narrative, is seen to produce enough food. The challenges are perceived as related to distribution, the reduction of waste, and the nature of food systems rather than increased production (see Soil Association 2010; International Civil Society Organizations 2015). In this light, SI is seen to represent a "wolf in sheep's clothing" (Wezel et al. 2015:1288) paving the way for

[3] Originally said about the then rapidly popularizing social capital concept: "Social capital, while not all things to all people, is many things to many people" (Narayan and Pritchett 1997:2).

[4] Rockström and Karlberg identify 4 squeezes: Population growth, climate change, deteriorated ecosystem functions and 'surprise' such as unpredictable tipping elements.

‘greenwashing’ that leads to perpetuation of unnecessary and wasteful ‘productivism’[5] in a world of finite resources (see International Civil Society Organizations 2015).

However, the *food first* and *feed the 9+ billion* narratives are pervasive. The 2014 Standing Committee on Agricultural Research (SCAR Foresight 2014), while acknowledging that distributive policies and reduction of waste are indeed ingredients in improving the state of affairs as regards future food security, also argues that these steps will not suffice. Godfray (2015) in the same vein convincingly argues that the quest for better distribution, while part of the complex picture, ignores the realities of political economy. Referring to Sen’s (1981) research on famines and his findings on the importance of stable food prices, Godfray points out that sustainable intensification “aims to reduce global hunger by increasing food supply in low-income countries and helping the global food system maintain affordable food prices and reduce volatility in global commodity markets.” (2015:204).

Generally seen though, these competing narratives do find common ground in their criticism of ‘high external input’ agriculture. This criticism resonates with Pretty’s (1997) and Conway’s (1997) original contrasting (see section 2) of green revolution (in the developing world) and industrial agriculture (in the developed world) with SI.

In this regard, it is worth keeping in mind that in Sub-Saharan Africa – a region that is central to the ‘*feed the 9+ billion*’ narrative for both demographic and agricultural reasons – modernizing agriculture along the lines of the Asian green revolution experience is a popular policy aim (Action Aid 2009). Asia’s green revolution saw vast increases in food production, but also a dependence on external inputs that often proved to be precarious for small farmers owing, in particular, to their limited access to financial capital. The green revolution formula remains, in the eyes of its critics, associated with monocultures, plant disease susceptibility, nutrient surpluses and emissions. Environmentally and socially unsustainable, the approach is seen to translate into reduced resilience for small farmers, in the face of climate change and climate variability (see ACB 2016; FAO 2014).

However, the research and policy agendas, and the agricultural directions that they support in Africa are blurred. The influential Alliance for a Green Revolution in Africa (AGRA), financed by the Gates Foundation, promotes green revolution technology ‘packages’ that are criticized for rendering smallholder systems vulnerable (Fejerskov 2017). At the same time, the research

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[5] Defining ‘productivist agriculture’ Woods (2011), refers to a “discourse of agricultural organization in which the function of farming was singularly conceived as the production of food and fibre, and which prioritized increasing agricultural production over all other considerations” (2011:67) . The associated notion of post-productivist agriculture emerged in the 1990’s (as did SI), to explain perceived changes in agricultural production, away from productivism, towards “demands for amenities, ecosystem services and preservation of cultural landscapes” (Almstedt 2013:8)

strategies of another influential organization, the Forum for Agricultural Research in Africa (FARA), commonly a partner in European – African research collaboration projects, while adopting SI as the main "organizing framework" (FARA 2014:8), also aligns itself with agricultural transformation experiences that entail green revolution and industrial agriculture directions[6].

5. SI and Related Approaches: What is the Difference?

Having in the previous section outlined the boundaries of SI by examining contrasting perspectives, SI will, in the following, be examined in the context of related 'low external input' intensification approaches. Wezel et al. (2015) in a comprehensive literature review compare three approaches, all of which feature prominently in current debates on the direction of agriculture, viz: 'Ecological intensification', 'sustainable intensification' and 'agroecological intensification'. As Wezel et al (2015) point out, SI is the most frequently occurring term in the literature.

Noting that these approaches are united in their adherence to principles of sustainability and the intensification of agriculture to meet food demands while mitigating environmental effects, Wezel et al. find that the principles differ on the following accounts: SI, as the most general category accommodates "most current farming practices…..as long as sustainability is in some way addressed" (2015:1283). Ecological intensification, "emphasizes the understanding and intensification of biological and ecological processes and functions of agroecosystems" (2015:1283), while "agroecological intensification accentuates the system approach and integrates more cultural and social perspectives in its concept" (2014:1283).

Table 1 summarises the keywords as they appear in 241 scientific papers on the farming practices of ecological intensification, agroecological intensification and SI between 1983 and 2015. It appears that the overlap between SI and ecological intensification is the strongest, even if wording and exact definitions of farming practices differ. The ecological intensification concept was originally coined by Cassmann (1999) as a set of ideas on ecological processes in yield enhancement in temperate arable crops (Godfray 2015); indeed, the ecological intensification vision comes close to that of SI.

The overlaps between SI, ecological intensification and agroecological intensification farming practices are also evident, even if the more comprehensive systems approach of agroecological intensification represents a major difference. Had the list included the social and cultural practices of agroecology, such as those associated with small farmers, local knowledge, local context and organisation, rather than predominantly agronomic practices, then the differences between agroecological intensification and the two other approaches would have been greater, as Wezel et al. (2015) note.

[6] The experience of Brazil, Thailand, China and South Korea in transforming agriculture

Table 1

Summary of Emphases in Ecological, Agroecological and Sustainable Intensification Farming Practices (as appearing in key literature)

ECOLOGICAL INTENSIFICATION	**AGROECOLOGICAL INTENSIFICATION**	**SUSTAINABLE INTENSIFICATION**
Conservation Tillage Mixed Cropping Systems Diversified Crop Rotation Cover Crops Minimisation of Soil Compaction Integrated Pest Management Improved fertiliser and Nutrient Management Direct Seeding Biodiversity Preservation	Mulching Intercropping Crop Rotations Integrated Pest Management and Biological Control Integrated Soil and Nutrient Management Balanced and Efficient Use of Fertilisers Use of Quality Seeds of Well-Adapted Hybrids Water Conservation Organic Inputs 'Right-time' Planting Crop-Tree-Livestock Interactions Recycling of Biomass and Agricultural By-products	Conservation Tillage Legumes, Cover Crops and Catch Crops in Rotations Integrated Pest Management Soil Conservation On-farm Mechanisation Smart, Precision Technologies for Irrigation and Nutrient Use Efficiency High Yielding Varieties (incl Transgenic Crops) Animal-Crop Integration

Based on Wezel et al. 2015

6. SI and the 'Neutral' Role of Technology

As Table 1 shows, a major difference between SI and ecological and agroecological intensification is SI's focus on technology (farm mechanisation, smart agriculture and high-yielding varieties) in farming practices. This illustrates the centrality of technology to the food first and *feed the 9+*

billion narratives of which SI is part (see section 4). It also suggests that sustainable agriculture in SI thinking is perceived as a predominantly technological challenge, without the (techno)political implications associated with unequal access to knowledge and finance (see Fejerskov 2017). This is particularly evident when comparing SI with agroecology's recognition of the social and cultural implications of certain technologies. SI ignores, for instance, the very divisive issue of GMOs and proprietary rights and claims (Godfray 2015). In this connection, there is very limited focus on small farmers' limitations as regards access to technologies, and as critics hold, genetic engineering as something that may increase the vulnerability of smallholder farming systems (Fejerskov 2017). Evidently, small is not necessarily beautiful (see Schumacher 1973) in SI.

These concerns gain particular relevance when considering that it is in the developing world that the population, food and climate squeeze will be most severe, and where, as Rockström et al (2016) point out, the "2.5 billion smallholders that control 500 million small farms and which produce 80% of the food supply in Asia and Sub-Saharan Africa reside". This silence as regards the structuring of rural development and farming, may be seen as indicative of the SI literature's relative neutrality as regards the strategy for sustainably '*feeding the 9+ billion*', most of it stressing, as Godfray puts it, "the goal rather than the trajectory" (2015:205).

Moving away from GMOs, and into less contentious technologies, the potential of digital technologies is reflected in the SI emphasis on precision technologies. Indeed, increasingly, the combination of the use of sensors, decision support systems and precision farming, for optimizing the use of resources in spatially targeted and site-specific management is becoming a central element in SI thinking. SCAR Foresight (2014), for instance, recognises digital technologies as technologies that potentially enable sustainable intensification, by reducing carbon and nitrogen footprints, improving soil quality, and enabling diverse production systems that, at different scales, produce a diversity of outputs.

As with other technologies, the full potential of digital technology for SI remains hampered by unequal access to technologies across the globe; however, engineering approaches that involve users in innovation of technologies in local contexts (Lomas 2016) may go some way towards bridging access gaps. So may, as argued by Conway and Badiane (2016), the continuously improving internet connectivity across the developing world, with Global Positioning Systems, micro-dosing of fertilisers and precision use of water as key features.

7. Concluding Remarks

This investigation of the definitions, principles and boundaries of SI has identified the following as key SI principles: Sustainability (eliminating harm/reducing negative impacts/improving environmental management of land), resource efficiency, limited conversion of land, yield gap closure and total factor productivity. Rooted in these principles, three major boundaries with contrasting and related approaches have been identified:

First, SI has taken intensification and productivity notions beyond high external input agriculture understandings, to include resource efficiency dimensions and total factor productivity as the key sources of productivity gains. This paradigm shift represents a major boundary vis-à-vis productivist directions in agriculture. With the advent of nexus and demographic, climate etc. 'squeeze' thinking, the SI paradigm has become firmly placed within the 'feed the 9 billion by 2050' narrative.

Secondly, SI's silence with respect to how farming should be structured in order to reach the goal of higher yields with less impact on the environment, represents a boundary vis-à-vis related sustainable agriculture directions, particularly agroecological intensification. SI mainly denotes a goal, and as both the critical literature and that which tends to champion SI points out, what to do to reach that goal is a work in progress. SI's limitations as regards prescriptive and strategic actions contrasts with agroecological intensification. The latter's broad systems approach, with focus on not only farming, but also political, social and cultural dimensions appears increasingly, at least in some contexts, as a framework for implementation.

A third boundary is represented by SI's embracing of new technology. This again confirms SI's centrality to the '*feed the 9+ billion narrative'* where technology plays a major role, and it contrasts with the approaches that compete within the sustainable agricultural realm. A fault line here is clearly the perception in SI, of technology as a neutral means towards intensification. This contrasts with perceptions of the role of technology – most clearly GMOs – in agroecological intensification thinking, as having negative effects on small farmers. In this perspective, SI and the narratives of which it is part, are obviously deeply political.

It is tempting to argue, that SI's relative silence with respect to the complexities and the politically determined structuring of farming, in the course towards the goal of higher yields and sustainability, is indeed the key reason why the approach is *many things to many people*. However, it may also be argued, as Pretty and Bharucha do, that because agricultural systems are "diverse, synergistic and tailored to their particular social- ecological contexts…..there are many pathways towards agricultural sustainability, and no single configuration of technologies, inputs and ecological management is more likely to be more widely applicable than another" 2014:1577-1578).

In this light, the strength of SI as a unifying concept appears to be its relative pragmatism, with scope for adaptation to specific circumstances, within the boundaries of its key environmental sustainability principles. This implies that SI's role as an organizing framework for research, in line with the recommendations of much of the SI literature, needs to be sustained through context-specific conceptual refinement, metrics and the testing of actual farming practices.

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