Conceptualising fields of action for sustainable intensification – A systematic literature review and application to regional case studies

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Review

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ABSTRACT

After two decades of research on sustainable intensification (SI), namely securing food production on less environmental cost, heterogeneous understandings and perspectives prevail in a broad and partly fragmented scientific literature. Structuring and consolidating contributions to provide practice-oriented guidelines are lacking. The objectives of this study are to (1) comprehensively explore the academic SI literature, (2) propose an implementation-oriented conceptual framework, and (3) demonstrate its applicability for region-specific problem settings. In a systematic literature review of 349 papers covering the international literature of 20 years of SI research, we identified SI practices and analysed temporal, spatial and disciplinary trends and foci. Based on key SI practices, a conceptual framework was developed differentiating four fields of action from farm to regional and landscape scale and from land use to structural optimisation. Its applicability to derive region-specific SI solutions was successfully tested through stakeholder processes in four European case studies. Disciplinary boundaries and the separation of the temporal and spatial strands in the literature prevent a holistic address of SI. This leads to the dominance of research describing SI practices in isolation, mainly on the farm scale. Coordinated actions on the regional scale and the coupling of multiple practices are comparatively underrepresented. Results from the case studies demonstrate that implementation is extremely context-sensitive and thus crucially depends on the situational knowledge of farmers and stakeholders. Although, there is no 'one size fits all' solution, practitioners in all regions identified the need for integrated solutions and common action to implement suitable SI strategies at the regional landscape level and in local ecosystems.

1. Introduction

Responding to increasing global food demand, food production has kept pace so far through agricultural expansion and intensification (FAO, 2009; Tilman et al., 2011; Stevenson et al., 2013). Future prospects are, however, controversial. Whereas some estimate further increases in food production (Ewert et al., 2005), others assume stagnating or decreasing crop yields due to the limited and increasingly degraded land and natural resource base and impacts caused by climate change (FAO, 2009; Ray et al., 2012; Stevenson et al., 2013; Eitelberg et al., 2015).

Against this background, the notion of sustainable intensification of agriculture (SI) has received growing attention in its ambition to simultaneously tackle food security and environmental challenges. In the last two decades, SI research has shown manifold new paths on how to combine the maintenance or increase of agricultural production (Garnett et al., 2013; Röös et al., 2017) on the same area of land (Godfray et al., 2010) and the contribution to sustainable development in a balanced way (Gadanakis et al., 2015). However, with rising popularity, the scope and objectives of SI have been increasingly widened due to the variety of disciplinary perspectives, suggested SI practices and geographical foci of interest. SI embraces a broad range of practices and contexts, including smallholder agriculture in developing countries and agro-ecological principles as well as the application of new technologies and management styles (Baulcombe et al., 2009; Foresight, 2011). Further research foci have been set on technological advances

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and the assessment of SI from a global perspectives (Baulcombe et al., 2009; Tilman et al., 2011), the resilience and durability of production (Dile et al., 2013; The Montpellier Panel Report, 2013) as well as better knowledge of the production process (Buckwell et al., 2014). In line with these developments, SI has been connected to the provision of ecosystem services and economic, social and ethical aspects of sustainability (Barnes and Poole, 2012; Garnett and Godfray, 2012; Smith, 2013) or to the generation of multiple benefits. Godfray (2015) also highlight the role of SI for changing the food system as a whole, which includes questions of food supply chains, consumption patterns and food waste and losses.

Accordingly, controversies persist regarding the understanding of the scope and scale of sustainability or environmental goals (Buckwell et al., 2014; Petersen and Snapp, 2015), the extent of the environmental benefits generated, and negative effects mitigated (Pretty, 1997; Baulcombe et al., 2009; Garnett et al., 2013) or compensated elsewhere (Franks, 2014). The latter case even allows for intensification in some locations if associated negative impacts are counterbalanced by positive environmental impacts at another place. Given the need for action to simultaneously address issues of food security, increasingly limited natural resources (Cordell et al., 2009), environmental degradation (Smith et al., 2016), and climate change adaptation (Thornton and Herrero, 2015), more emphasis on the elemental principles of SI, namely the aspiration to increase food production on less environmental costs, is essential. Rather than a specific practice or set of practices, SI constitutes this aspiration as a goal (Garnett et al., 2013). Stronger orientation on implementation is needed, which in turn requires consideration of the regional and situational context, the selection and application of SI practices depends on (Godfray and Garnett, 2014). Therefore a clear and unbiased framework for the selection is required. In this regard, an acknowledgement and systematic structuring of the various ideas on SI implementation found in the scientific literature can support decision-making in practice and simultaneously contribute to a tangible conceptual understanding of SI.

Based on a systematic literature review, the objectives of this study are (1) to comprehensively explore the SI literature and provide a structured analysis of the diversity and scope of SI research and knowledge, (2) to propose an action-oriented conceptual framework on the basis of the portfolio of existing SI practices, and (3) to demonstrate its applicability to identify SI practices for region-specific problem settings in selected European case studies using a participatory stakeholder process. Findings concerning the three objectives are provided in separate sections (3–5), resulting in one proposition per objective, which are then resumed, discussed and connected in Section 6.

2. Methodology

We have carried out a systematic review of the existing literature in the field of sustainable intensification to obtain an interdisciplinary and comprehensive overview of the topic (von Döhren and Haase, 2015; Gao et al., 2017). Subsequently, we intertwined the review with the development of a conceptual framework of SI practices. First, the materials for analysis were selected by using the two main collections of academic literature, the Scopus database (www.scopus.com/) and Web of Science (https://webofknowledge.com/) (Aghaei Chadegani et al., 2013; Harzing and Alakangas, 2016). We applied the search term 'sustainable intensification' in title, author keywords or abstract for all research articles and review papers, which had been published before December 31st, 2016. In doing so, we deliberately captured only literature that focuses closely on SI. Our final database was composed of 349 papers. The overlap of the two sources of literature comprises 271 articles, 59 are exclusively collected by Scopus and 19 by Web of Science respectively. Each article's meta data was recorded. This included the year of publication, keywords, the publishing journal, and both internal citations by other articles within our article sample (available for Scopus data only) and external citations in articles which are beyond this SI literature. We also included the geographic coverage for systematic analysis using information from abstracts and keyword search. All retrieved information was descriptively evaluated.

For a systematic description of the content of the selected papers, categories for analysis need to be defined in accordance with the research aim (Brewerton and Millward, 2001; Harkonen et al., 2015). In categorising, we addressed the practical implementation of SI in three taxonomic layers. The bottom is built by the concrete, practical actions an actor takes to implement SI which we collected from abstracts and conclusions of the articles. We refer to them as SI *practices* throughout the paper. Due to their diversity, the single SI practices are summarized in bundles of similar practices making up general SI *approaches*, our second taxonomic layer. As a third layer, four categories were derived from two discriminating dimensions namely spatial scale and activity scope of SI. The identified SI approaches were assigned to the categories named *fields of action* (FoA) for SI. They are the basis for a conceptual framework of SI. We collected 646 SI practices in the 349 articles which we summarized in 26 SI approaches. Although to some extent personal valuation guides assignment to the four FoA, the consistency of the final solution was verified by multiple rounds of cross-checks by researchers from different disciplines (incl. economics, geography, natural resource management, agricultural sciences). The final database is available through an additional data publication (Weltin et al., 2017).

The applicability of the framework to specific regional problem settings was tested in four regional European case studies through participatory processes with in total 68 stakeholders involved in land-use decisions (incl. agriculture, administration, environment, research). Case study regions were selected in order to capture a variety of geographical contexts, land use and landscape characteristics (van der Zanden et al., 2016). The participatory methodology was selected as a useful tool for the production of region-specific knowledge from the direct involvement of key stakeholders in the diagnosis of SI implementation (Kemmis et al., 2014). We drew on the methods of Reed et al. (2009) and started the fieldwork with in-depth interviews with farmers and other stakeholders relevant for implementing SI practices followed by a snowball sampling to identify the stakeholders that are part of each agrarian system. The second phase of the analysis was the organisation of a participatory workshop in the four European case studies. Methodological guidelines were elaborated to ensure that the workshops enabled the cross-comparison of the results. The main objectives of the workshops were: (i) to present to the stakeholders the four FoA stemming from the SI conceptual framework, (ii) to discuss the SI practices that are currently applied, commonly categorising them into the four FoA; and (iii) to stimulate stakeholders to share their understanding of possible future SI practices for their region. Results on current and future SI practices were descriptively evaluated and compared across regions.

3. Scope of the SI literature

3.1. Development of the SI literature

Initially introduced by Pretty (1997), the SI literature can be divided into three phases reflected by the temporal and geographical development of publications (Fig. 1). It originated in parallel to the mainstreaming of sustainability initialised by the Brundtland Report (1987) and the rise of the ecosystem service concept (Costanza et al., 1997; Daily, 1997), bringing environmental emancipation into the economic domain (Goodland and Daly, 1996). In a first phase (1997–2008), SI evolved to mainly explore the possibilities to support smallholder agriculture and livelihoods in Africa, Asia and Latin America while generating environmental benefits (Clay et al., 1998; Shiferaw and Holden, 1998). Research in this phase focussed on the improvement of underutilised land, the role of local knowledge and embeddedness in local social networks and institutions (Bebbington, 1997; Pretty, 1997). The first three years resembled a kick-off for SI research with 11

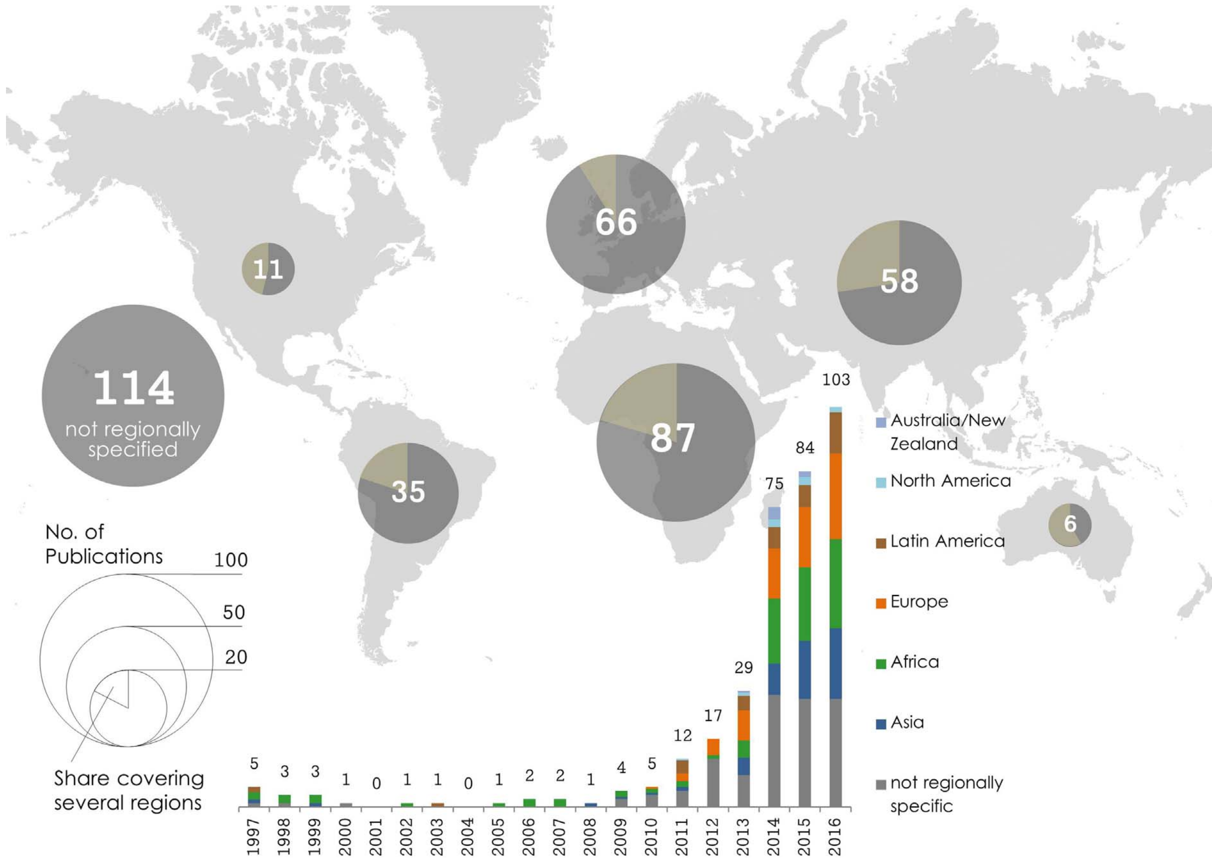

Fig. 1. Geographical and temporal distribution of published studies (N = 349).
Source: Own representation.

publications, which was later largely marginalised between 2000 and 2008.

After the food price crisis in 2007/08, the number of SI publications showed an increasing trend, accompanied by a growing and robust body of evidence on environmental degradation and biodiversity loss due to agriculture (MEA, 2005) and the intensifying research on climate change (McCarthy et al., 2001; Parry et al., 2007). The second phase of the SI research (2009–2013) was complemented by resource efficiency-oriented and technology-related publications (Balasubramanian et al., 2007; Flavell, 2010). Emphasizing the need to produce 'more food on a sustainable basis with minimal use of additional land' (Baulcombe et al., 2009), they highlighted a great need for innovation, the application of new technologies and the insights of biological and crop sciences, including breeding and genetic improvements (Foresight, 2011). SI slowly gained renewed resonance in other parts of the world, particularly for the intensive European agricultural systems. This also included advancements in indicator developments for the assessment of trade-offs between economic and environmental objectives of agriculture (Geniaux et al., 2009). However, in North America as well as in Australia and New Zealand, the term 'sustainable intensification' had hardly entered the scientific literature.

The third most recent phase of the SI research (2014–2016) was characterised by a rapid expansion of research and publication activities focussing on farming systems around the world. These three years alone covered 75% of all reviewed publications and are accompanied by a further widening of the discussed topics. However, after the sharp increase of publications on SI in the year 2014 (+159%), growth has been slowing down again in 2015 (+12%) and 2016 (+23%). Recent literature stressed that SI can only be a part, albeit an important one, of multidimensional strategies to achieve food security (Godfray and Garnett, 2014; Davis et al., 2016) and resilient agriculture within a globally sustainable future (Rockström et al., 2016). Additional to the scientific literature, the notion of SI has increasingly entered the political domain, as it has been part of the reform process of the European Common Agricultural Policy (CAP) because of the commissioning of the RISE report on SI implementation and evaluation with a clear policy horizon (Buckwell et al., 2014).

3.2. Systematic appraisal of the SI literature

The keywords of articles, which authors use to indicate the focus of their work or to connect it to other scientific strands of literature, provide a first insight into the wide diversity of topics covered by the SI literature. Overall 937 different keywords were used in the selected publications. More than one third of the articles (39.5%) use the term 'sustainable intensification' in keywords. Searching for commonalities in the SI research, we found however that there is no keyword unifying a very large share of the articles. The diversity of keywords can already be represented by analysing those 27 keywords that make up the first quartile of all keywords ordered by highest use. They are used in at least six articles equal to only 1.7% of publications (Fig. 2a). The most frequent keyword other than 'sustainable intensification' itself is 'food security', which relates to one of the main aims of SI (Pretty, 1997) and is only used by 14.9% of the articles. It is followed by 'ecosystem services' (7.7%), another important research strand (Costanza et al., 1997; MEA, 2005), underlining the influence of ecosystem services research on SI research. Keywords describing how SI should be achieved indicate a broad scope for implementation. They include 'intensification' as well as 'agro-ecology' or 'conservation agriculture', which are frequently formulated as contradictions to the former (Marsden, 2010), and range from 'land sparing' for conservation activities to closing 'yield gaps' and implementing 'innovations'.

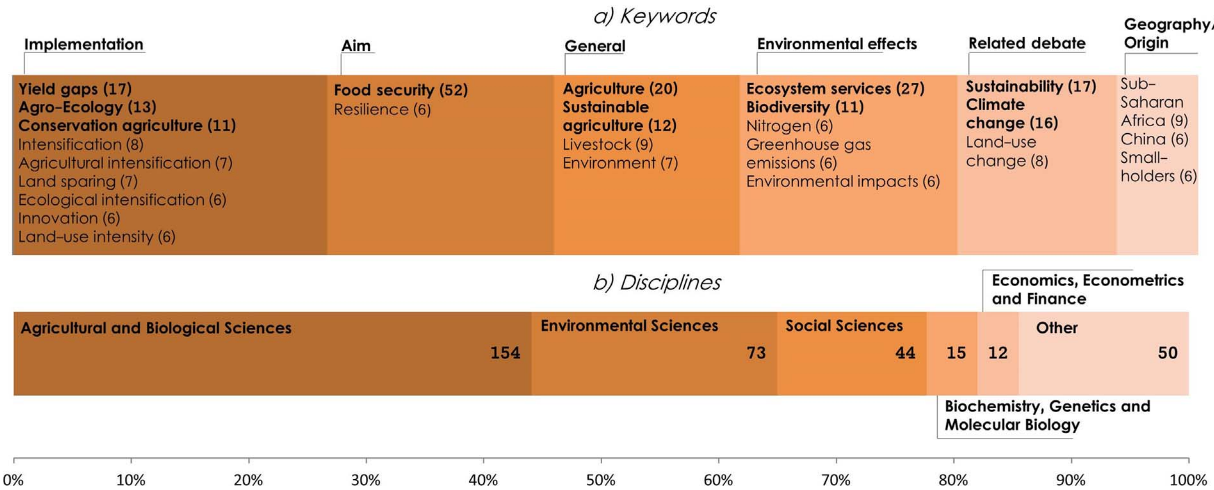

Fig. 2. Thematic focus of the selected articles (N = 349) represented by (a) most frequently used keywords (min. six times, singular and plural versions were counted as one keyword, the 10 most frequent keywords are marked in bold) and (b) scientific discipline of the journals. Categorisation of disciplines based on Scimago Journal and Country Rank portal's classification of subject areas http://www.scimagojr.com/. Category "other" contains 5 journals not listed. Publications with several disciplines contribute in equal shares to each of them.
Source: Own representation.

The SI literature spreads across diverse research areas and journals. The articles were assigned to their main scientific disciplines. The selected papers were published in 176 journals and cover 22 disciplines with agricultural and biological (44%), and environmental sciences (21%) enjoying predominance (Fig. 2b). In comparison, SI is underrepresented in the social sciences and in economics, which are key to discussing how relevant actors can be incentivized to adopt SI practices.

As measured by the number of absolute citations, both within the sample of SI literature and outside by other scientific articles (Fig. 3, for Scopus data only), there are few SI publications with very high impact, also considering the fact that the majority of the papers are published between 2014 and 2016. The number of external citations measures the attention that the literature receives for questions beyond the core of SI. The number of citations within the selected publications identifies the

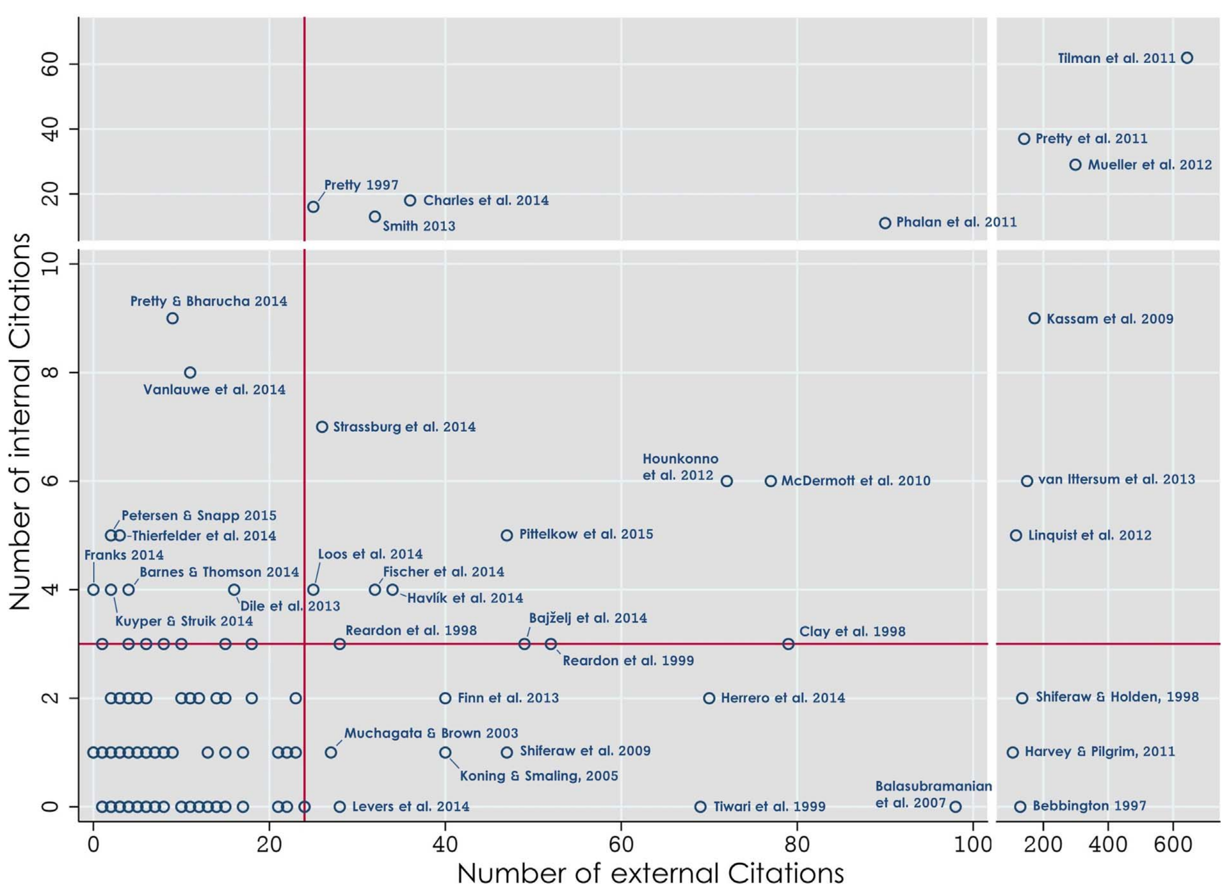

Fig. 3. Relationship of external and internal citations in the analysed literature. Based on Scopus database and citation records (N = 330). Two additional solid (red in web version) lines represent the 90% quantiles of the respective axes. The citations of 194 articles do not exceed both quantiles. 96 papers are not cited and, therefore, excluded.
Source: Own representation.

key contributions to the SI literature. Whereas 96 papers are not cited at all (70% of them are recently published in 2016), only 40 papers have more than either 3 internal or 24 external citations (90% quantiles). 37.5% of these were published between 2014 and 2016. The 40 papers can be again separated into three groups: those which are exclusively relevant for the internal or external literature (8 and 15 respectively), and those which are highly appreciated by both (17).

Citation records range up to 182 for external citations and 18 for internal citations except for three outliers. These three papers (Pretty et al., 2011; Tilman et al., 2011; Mueller et al., 2012) show a rather outstanding position. With the development of African agriculture (Pretty et al., 2011), greenhouse gas emissions and global nitrogen use in different agricultural production scenarios (Tilman et al., 2011) and yield gaps (Mueller et al., 2012), these papers cover frequently addressed topics in the SI literature, but are also of interest for non-SI research. Other highly relevant contributions discuss particular SI approaches such as conservation agriculture (Kassam et al., 2009) and land sparing (Phalan et al., 2011a).

Looking at the publications of internally high impact, measured in high citation records, the literature concentrates around the last five years. Only three publications above the internal 90%-quantile are older. From the initial phase of SI literature (1997–2008), only Pretty (1997) with 16 internal citations has been internally cited more than three times. This indicates a thematic shift with a marked disconnection of the subsequent SI research from the initial literature. Although the initial publications are of little relevance for the sample of SI literature internally, they are fairly well recognized externally. Additionally, no unifying paper for the SI research stands out. Comparably relevant articles that discuss the multitude of SI approaches in several systems (Pretty and Bharucha, 2014; Vanlauwe et al., 2014) are only cited by around 5% of subsequent articles.

Summarising our observations on the SI literature, we find temporal phases of stagnation, revival and sharp rise with different foci indicating thematic breaks alongside other parallel research topics. The uptake started at different times in different world regions and some are still neglected. Wide spread of related topics and keywords, broad but unbalanced disciplinary coverage and rather loose internal connection point towards high diversity and complexity of the topic. This leads us to the first proposition, that heterogeneity in perspectives from which SI is discussed exists. A systematisation is required for a more integrated understanding of the existing knowledge on SI and the identification of existing research gaps.

4. Conceptual framework: fields of action for sustainable intensification

4.1. Differentiating SI dimensions

To support conceptual development, a procedure based on practical implementation of SI was chosen. Corresponding to the heterogeneous SI research, a broad and diverse portfolio of SI practices was identified in the selected articles. We distinguish SI practices according to (1) the spatial scale whether they are carried out at a farm or landscape level, and (2) the activity scope from a land-use to structural optimisation, as these dimensions have been chosen as scaling issues (Gunton et al., 2016). Land use (Phalan et al., 2011b), structural adjustments of production system and efficiency approaches (Pretty and Bharucha, 2014) are frequently discussed in the literature to differentiate the notion of SI.

4.1.1. Spatial scale of SI: farm and landscape level

Like agriculture and land-use management in general, SI approaches are very much scale-dependent. Certain practices, mainly related to agronomy and input efficiency, are predominantly limited to the field and farm level. For those SI practices, the farm system represents the entity for which processes and outputs are optimised. SI practices are usually implemented by individual innovative changes on the farm, such as new breeds or cropping patterns or farm management tools. On the farm level, SI practices are also stimulated through regular agricultural extension services, environmental regulations and standards, or public policies (World Bank, 2007; Avolio et al., 2014). Other practices require consideration of the situation beyond the farm gate. Their implementation and effects depend on the scales of the ecological and human systems they are interacting with (Ferreyra et al., 2008; Duru et al., 2015), which usually manifest at regional and landscape or watershed level (Lefebvre et al., 2015). The research about land sparing and land sharing and their contribution to biodiversity is, for example, very scale-dependent either segregating areas for production and conservation at larger scales versus integrated on-site conservation efforts (Phalan et al., 2011b). Other SI approaches draw on the value added, which is generated through the pro-active embeddedness of the farm into the larger regional context, e.g. through coordinated actions, cooperation in supply chains or knowledge exchange (Hinrichs, 2003; Morgan, 2011). Due to the multitude of actors, stakeholders and farmers involved, the implementation depends on spatially coherent and well-functioning institutions and governance structures to cope with the complexity of regional conditions and requirements, social interactions, conventions and interests (Armitage et al., 2012; Zasada et al., 2017).

4.1.2. Activity scope of SI: land use and structural optimisation

The SI literature covers a broad set of very different practices (Pretty and Bharucha, 2014) depicted in the activity scope – either focussing on land-use or structural aspects. The former is closely linked to agricultural and agronomic questions of practices related to changes in cultivation and livestock rearing as well as to land use and landscape planning. The latter relates to strategic planning and organisation of production processes, inputs and resource use at the farm and beyond as well as interactions and exchange among actors. Regarding the optimisation of land use, SI practices include the use of novel or more environmentally effective practices of cultivation and livestock rearing (Foresight, 2011), e.g. precision farming or crop-livestock integration as well as targeted decisions on the purpose land should be used for depending on its site characteristics and functions (Coyle et al., 2016). However, it was shown that resource use efficiency assessments are affected by whether or not they include environmental outputs (Areal et al., 2012). Therefore, another angle from which to address the activity scope is the use of resources such as natural and non-renewable inputs, labour and knowledge, both on the farm and beyond. Management of all available resources including human resources increase productivity, reduce non-renewable input use and enable the regional exchange of knowledge and resources (Buckwell et al., 2014; Loos et al., 2014). Investments for the improvement of human capital and efficient resource use are well-known success strategies to create synergies between economic development and environmental sustainability (Goodland and Daly, 1996). This perspective of SI focusses on the management cycle of production and implies a structural optimisation. Land use and structural optimisation form the endpoints of a gradient that determines the activity scope of SI. Practices can share aspects of both such as precision farming, which is a new technology especially spatially-targeted to apply inputs efficiently.

4.2. A conceptual framework of sustainable intensification

The combination of the two dimensions of spatial scale and activity scope of SI establishes four fields of action (FoA) that unify SI practices and approaches and represent the baseline of an action-oriented conceptual framework of SI that integrates the heterogeneous literature. According to the SI practices and approaches assigned to the FoA, we label the fields of action FoA I ‘Agronomic Development’, FoA II ‘Resource Use Efficiency’, FoA III ‘Land Use Allocation’, and FoA IV ‘Regional Integration’. Fig. 4 provides an overview of the FoA, the

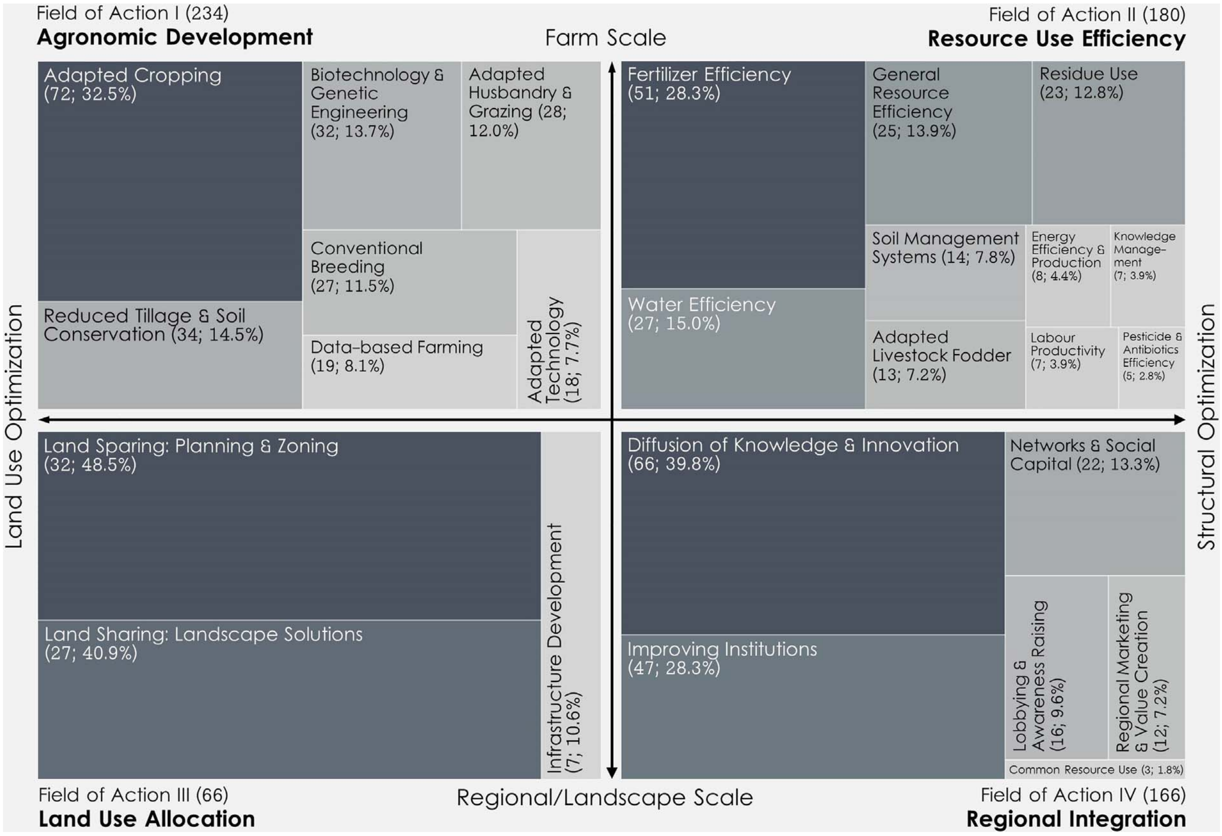

Fig. 4. Conceptual framework of SI: Fields of Action, related SI approaches as described in the 349 selected articles. One article can address several SI approaches. In parentheses: Frequency of the approach; Share of the approach within FoA, box sizes correspond with this share.
Source: Own representation.

assigned SI approaches including the number and share of mention in the articles.

4.2.1. Agronomic Development (FoA I)

A majority of practices (N = 234; 36%) are closely related to questions of agronomic development, either dealing with the cropping system, or to a lesser degree also with the livestock system. In order to reach agronomic objectives, such as increasing land productivity, crop yields and quality as well as sustainability goals, optimising cultivation methods or production techniques are proposed. Among the approaches, there is a clear focus on adapted cropping (N = 72; 33%). This includes crop rotations where cultivated crops directly impact the health status of succeeding crops and indirectly support them via the soil's physical and nutrient status. Intercropping and cropping pattern diversification utilise these effects by allocating preceding crops temporally targeted, while mixed cultures, strip cultivation, agri-horticultural or agroforestry systems allocate beneficial effects spatially targeted (Hellin et al., 2013; Mao et al., 2015; Nyagumbo et al., 2016).

Within a specific crop management system, practices embrace choice of variety and crop management including techniques from tillage to soil conservation (Giller et al., 2015; Townsend et al., 2016). Using practices of biotechnology and genetic engineering is more frequently mentioned (N = 32; 14%) than conventional breeding (N = 27; 12%), given their potential for crop yield and quality increase with improved resistance against water stress or pests and diseases. However, legal restrictions are also pointed out (Raybould and Poppy, 2012; Beaudoin et al., 2014; Harrison et al., 2014).

The strong interconnection of novel technical solutions, new digital technology applications and the use of site-specific information and system data are characteristic of first implemented 'smart' agronomic system solutions (Kidd, 2012; Ball et al., 2016), and the ongoing discussions towards future agronomic systems. Precision farming takes a central position here, as it allows for site-specific optimisation of cultivation, and is hence applicable both to intensive integrated (conventional) as well as organic farming systems (Gumma et al., 2016). Despite the development and existence of similar system approaches in husbandry, scholars rarely contextualise those in the frame of SI (Szabó and Halas, 2012). Our literature review mostly identified adapted grazing systems (N = 27; 12%; rotation, density management).

4.2.2. Resource Use Efficiency (FoA II)

SI practices in the second FoA (N = 180; 28%) circulate around approaches to efficiently handle the available natural, chemical, and human resources of an agricultural holding to reduce agricultural expenses, and/or environmental pressures. These papers highlight pathways to increased agricultural productivity by either using fewer inputs (resources) or producing more outputs. Natural resources include irrigation water, manure, residues and animal feed, while chemical resources include fertilizers and pesticides, and human resources encompass labour, knowledge and managerial abilities. The major approaches related to resource use efficiency found in the scientific literature relate to fertilizers (N = 51; 28%), residues (N = 23; 17%) and water (N = 27; 15%). In contrast, approaches associated with human resources, such as knowledge management and labour productivity are less frequently covered by current SI research.

Articles cover novel techniques of nutrient management practices to improve fertilizer efficiency (Suter et al., 2015; Wani et al., 2015) as well as measurements of related carbon, nitrogen, and phosphorus balances and losses (Linquist et al., 2012; Zhou and Butterbach-Bahl, 2014; Sattari et al., 2016). Irrigation has been examined as contributor to water scarcity and ecosystem damage, which is particularly relevant in drought-prone regions (Scherer and Pfister, 2016). Papers that

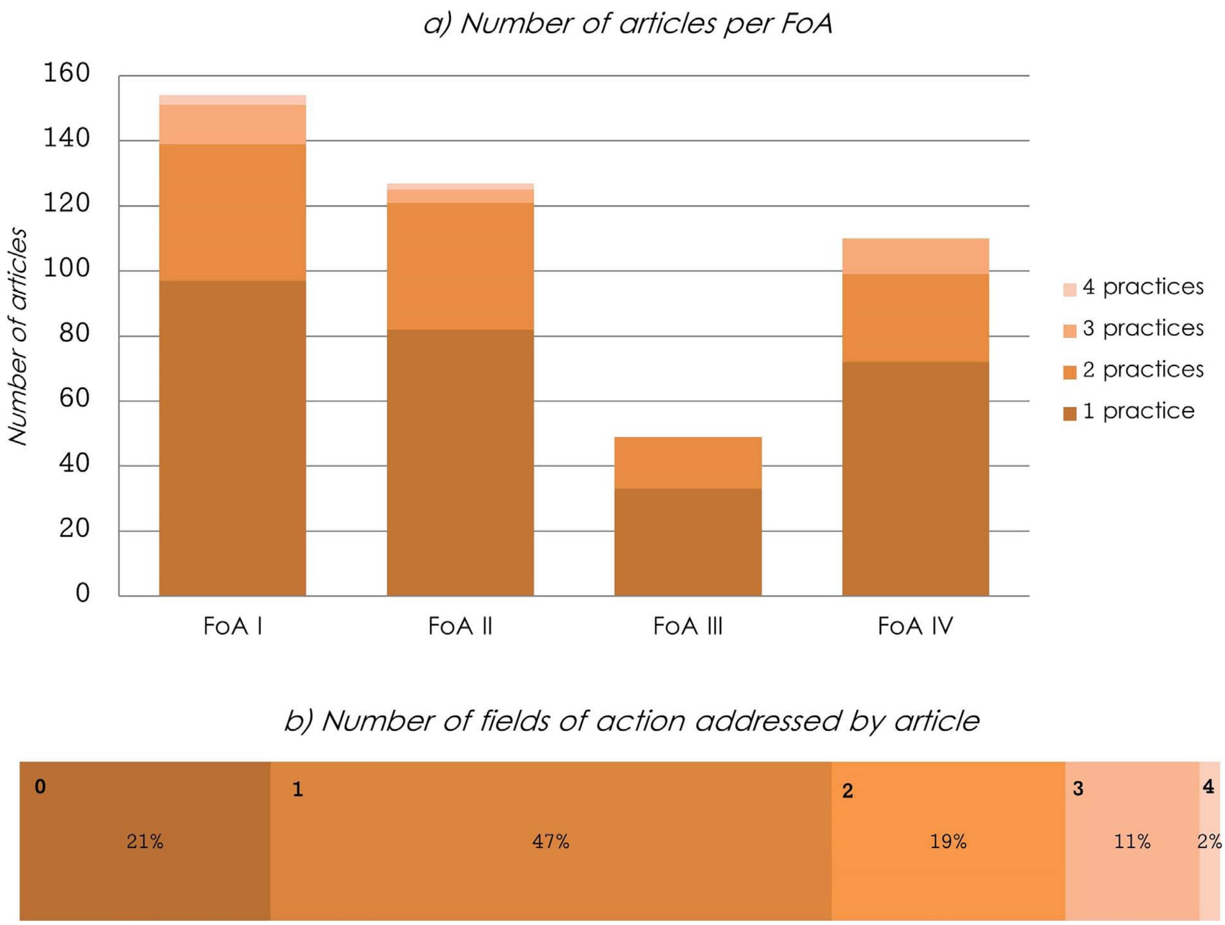

Fig. 5. Coverage of the FoA in the scientific literature (N = 349).
Source: Own representation.

outline methods for increasing water use efficiency were focussed on topics like marginal water use, integrated crop water management (Jägermeyr et al., 2016) or rainwater harvesting (Dile et al., 2013). Further, pesticide and antibiotics use (Ellis et al., 2016) and energy efficiency and production (Krupnik et al., 2015) are relevant SI topics, but are often found in conjunction with other SI practices.

The few knowledge and human resource-related studies demonstrate the effects these factors have on efficient resource use. Information on local environmental conditions, seasonal variability and crop requirements allow for optimisation of the timing and location of resource inputs (Gadanakis et al., 2015). Labour productivity is addressed with respect to the optimal planning of available labour input (Wang et al., 2016), synergy effects through diversification (Bunting et al., 2015) and the adjustment of farm and field sizes accordingly (Bos et al., 2013; Rusinamhodzi et al., 2016).

4.2.3. Land Use Allocation (FoA III)

Research which focusses on targeted and planned land use allocation based on regional needs and capacities in order to enhance landscape functioning and (agro-) biodiversity is included in FoA III 'Land Use Allocation' (N = 66; 10%). It includes approaches which aim at improving the joint provision of various environmental services in the same landscape and/or to produce the same amount of food and biomass on less land or in a different organisation of land.

A prominent part of the literature in this FoA concerns the elaborations about landscape design and its declination in the land sharing and land sparing SI approaches (Shackelford et al., 2015; Dauber and Miyake, 2016). The scarcity of land available for conversion to agriculture in order to feed the increasing population, combined with the parallel need of biodiversity conservation, requires the holistic integration of productive and natural spaces at the landscape level (Fischer et al., 2014) and the identification of possible innovative land use practices (Grau et al., 2013). Many examples of these two SI approaches are related to the coexistence on a specific landscape of agricultural production, such as livestock and pastures (Mastrangelo and Gavin, 2012) or coffee plantations (Gordon et al., 2007), and natural elements indicating a good level of biodiversity, such as native vegetation and birds. Mixed crop-livestock systems on the landscape scale are also included in this FoA. They increase the diversity within the agricultural systems and allow the improved regulation and maintenance of environmental services through a diversified landscape mosaic (Lemaire et al., 2014).

In the literature, most of the studies (N = 32; 49%) are focussed on planning and zoning. In some cases, they are concerned with improving coordination between input and output marketing systems (Reardon et al., 1997), whereas in other cases they act through the implementation of agro-environmental measures assuring the maintenance of specific societally supported agro-ecosystems (Hecht et al., 2016).

4.2.4. Regional Integration (FoA IV)

Focussing on approaches of structural improvements at regional level, the FoA 'Regional Integration' (N = 166, 26%) encompasses manifold topics of knowledge exchange and innovation diffusion, functioning of institutions, governance mechanisms and local networks. Many contributions highlight the important role of cooperation and exchange between different actors at the regional level for different purposes, such as common resource use, value chains and marketing strategies. This also includes non-farming actors, such as policy and decision-makers, the local community and economy at large.

Multi-level and multi-stakeholder networks are found to enable common resource use, redistribute inputs and close nutrient loops. Examples include regulatory schemes for irrigation management at the regional level (Pretty et al., 2011). This FoA also concerns the integration of actors in regional marketing activities. For instance, certification schemes establish a common regulatory framework for sustainable farming practices, improve the connection between producers and consumers and build consumer confidence (Buckwell et al., 2014). In addition, institutional changes such as taxation, land tenure policies or access to credits, but also improved forms of leadership and governance are highlighted as triggering SI (Southern et al., 2011; Bird, 2014).

With 40% of contributions to this field (N = 66) the most frequently addressed topic, however, is regarding the question of knowledge and innovation diffusion (Shiferaw and Holden, 1998; Buckwell et al., 2014; Campbell et al., 2014). Regional networks, which open channels of communication, awareness raising and trust among different actors (Bebbington, 1997) facilitate the diffusion of knowledge and novel practices. Other papers explicitly emphasise the role of extension services (Baulcombe et al., 2009), but also the effectiveness of farmer-to-farmer learning (Pretty et al., 2011).

4.2.5. Comparing fields of action for SI

The farm level is the dominant spatial scale on which SI practices are investigated. Addressing SI at a superordinate landscape level of regional land-use planning or steering societal interactions and regional integration is underrepresented in comparison (Fig. 5a). A major share of the literature (47%) takes a specialised perspective on SI as authors cover a particular field of action and then tend to focus on a single selected practice (Fig. 5b). More integrated perspectives rarely go beyond coupling more than two fields of action (13%). 21% of the papers do not consider practices of SI in abstracts or conclusions.

Altogether, the literature shows that a broad scope of the application of SI practices exists across and within FoA. This conceptual approach amalgamates and structures SI practices and thus the SI literature as facets and aspects of a multidimensional notion. The results can be summarised as the second proposition, that taking into account the differences in spatial scale and activity scope of SI allows the integration of the diverse SI practices within a common conceptual framework.

5. Application of the conceptual framework in regional case studies

To particularise the generic framework to specific regional settings, relevant SI practices are identified with the support of regional stakeholders involved in decisions on land use. The four case study regions are characterized by different land use practices, levels of intensity (van der Zanden et al., 2016), as well as ongoing change processes and future challenges (Fig. 6). Together, the case studies represent major agricultural land use types in Europe and cover a variety of situations in terms of urbanisation and environmental problems. The generic conceptual framework should be applicable to a wide range of regional settings.

The SI trends in the case studies reflect the diversity of the different land-use systems and challenges. Nonetheless, in each region the SI agenda addresses all four FoA. Fig. 7 depicts the results of stakeholders' assessments on the SI approaches currently applied and which they consider additionally relevant for the future. For the current and future situation, the frequencies with which any given SI approach was suggested as a solution are displayed. To account for different sizes of stakeholder groups and total suggested solutions, regional frequencies are weighted up or down to represent each region equally.

Focussing on the current situation, on the farm level in accordance with the literature adapted cropping practices (FoA I) are dominant. Further, efficiency gains especially in terms of pesticides, water, and residue use but also labour productivity mainly related to the restructuring of the farm income base play a role. Specificity becomes apparent in how the respective regions elaborate the FoA. Adapted cropping in the form of integrated farming systems is practiced in Vaucluse with horticulture and fruit orchards. New crops are introduced according to regional needs such as legumes delivering proteins for livestock in Rhinluch or almond trees which are less water dependent than vine in Utiel-Requena. Adapted husbandry is applied in the German case study via rotational grazing systems and adapted stocking densities. FoA II, 'Resource Use Efficiency', dominates in Vaucluse and Kromme Rijn. Specifically biological pest control and integrated pest management in the permanent crops typical for both regions are important. In Kromme Rijn, additionally the use of manure to close nutrient cycles is prominent, but mainly triggered by agricultural policy. Political support also incentivize actions to save water resources in Utiel-Requena, e.g. through underground drip irrigation. In the field of 'Land Use Allocation' (FoA III), the peak in land sharing practices mainly relates to the uptake of agri-environmental schemes promoting buffer strips, field margins and landscape elements. Land sparing is addressed through voluntary land allocation schemes to protect biodiversity which are taken up in the German and the Dutch cases. Regarding 'Regional Integration' (FoA IV), in the Vaucluse region short value chains are widespread and strictly related to its urbanised land structure. Spanish farms also engage in FoA IV via the exchange of manure with other farms and collective action of networks of neighbouring farmers such as fighting the grape moth.

Regarding currently missing SI approaches and future need for action, stakeholders in all regions strongly emphasize practices on the landscape and regional level in the field of 'Regional Integration' (FoA IV). Stakeholders suggest that future improvements should be prompted through collective action and public policy. Dutch stakeholders strongly demand improved institutions to standardise regulations within the EU and the increased sale of local products via retail chains, e.g. using common labels as a regional marketing strategy. Both practices aim to reduce external competition and thereby the financial pressure on local farmers. In terms of regional marketing and value creation, French and German stakeholders also see a need for improvements in the local agro-food chain underlining the importance of collective strategies among farmers for sales and promotion. In Vaucluse, the need for knowledge diffusion, namely through farmer education and agricultural experimentation is additionally highlighted. This view is shared by their Spanish counterparts who describe efficient water use and fertilization management as site-specific and knowledge-intensive. To be carried out appropriately, technical assistance and awareness raising among public (i.e. agricultural administration) as well as private agents (i.e. cooperatives) are suggested. Resource exchange in terms of administering common use is required in the area of regional water management. In Vaucluse, this addresses the irrigation network and in Rhinluch the drainage system. Networks and social capital are mainly raised as supporting requirements for implementing other practices. Stakeholders in Rhinluch identify tourism as an area in which farmers and other local stakeholders must cooperate to market the region as a recreational area and natural habitat. PDO labelling in Utiel-Requena has similar challenges to be addressed. It requires coordinated action, trust in the enforcement of common agreements, and a leading institution to increase grape quality, and thus revenues, by reducing production volumes.

The conceptual framework of the four FoA encouraged stakeholders to identify and discuss key challenges. Regional discussions yielded holistic SI agendas. The results from the case study regions with their diverse regional background situations lead us to our third proposition, that the specific context determines the relevance and design of regional SI solutions. There is 'no one size fits all'. Knowledge of regional farmers and stakeholders is required to explore suitable SI practices and their interaction with the local ecosystem.

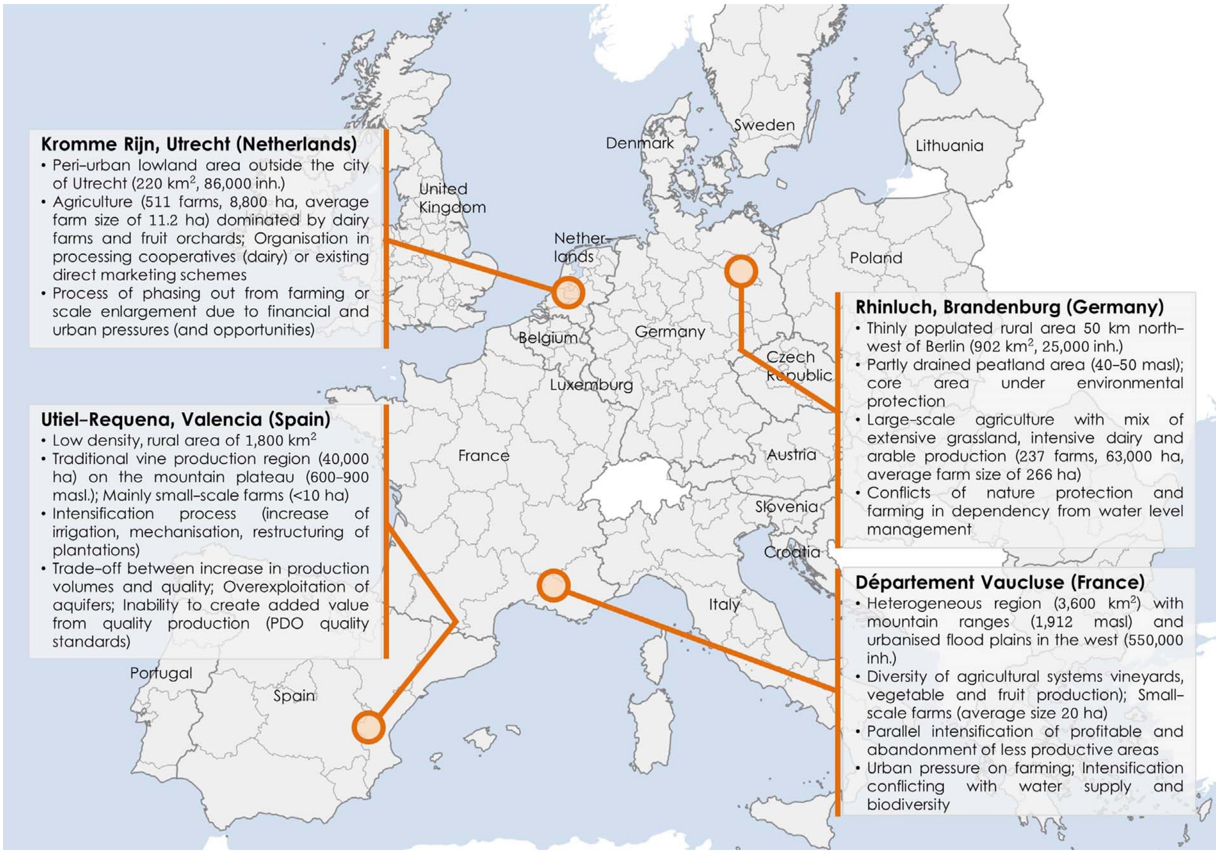

Fig. 6. Description of case study regions.
Source: Own representation.

6. Discussing and connecting perspectives on SI

6.1. Heterogeneity in the SI literature

As the consolidated development of the SI literature body – after a period of sharp increase – included in our database suggests, now is a suitable moment to retrospectively develop a comprehensive picture of the SI research through a systematic, interdisciplinary screening. The geographical pattern reflects ongoing political and societal discourses, starting from investigations of extensive systems mainly in the Global South, and moving to highly intensified systems of the Global North. Whereas in Europe SI attained increasing prominence from policy-making (Buckwell et al., 2014) as a reaction to increased environmental pressures (Baulcombe et al., 2009) and a long tradition of common agricultural policy-making, the experience of the deregulation of the agricultural sector in New Zealand has led the way to intensification and a departure from ecological sustainability (MacLeod and Moller, 2006). In the US some political documents even eschew the term 'sustainable' due to the term's negative connotations for some interest groups (Godfray and Garnett, 2014). This might explain why in both world regions, SI has been barely addressed as a scientific topic.

Results also point to a notable underrepresentation of SI in economics and social sciences compared to agricultural, biological and environmental sciences (Fig. 2b). This is certainly partly due to differences in the terminology used for the same or similar phenomena, such as eco-efficiency (Picazo-Tadeo et al., 2011; Areal et al., 2012) or joint production of marketed agricultural and non-marketed environmental goods (Wossink and Swinton, 2007). The use of the search term 'sustainable intensification' resulted in a narrow selection of articles, as we wanted to focus on authors who deliberately discuss their work under this terminology, being also aware that other parts of the research – which take place outside this narrow use of the notion – are neglected in the review.

Reluctance to use the term SI may be rooted in the partially normatively and ideologically loaded discourse surrounding it. Critics frame SI as an oxymoron (Struik et al., 2014; Mahon et al., 2017), a neo-productivist approach (Levidow, 2015) or a way to disguise the maintenance of the status-quo in agricultural production (McDonagh, 2014), whereas proponents speak of a new paradigm in environmental policy (Franks, 2014). Voices that call for midway strategies (Jordan and Davis, 2015) or for framing SI as one part of a multidimensional strategy for food security (Godfray and Garnett, 2014) might be overlooked. Disconnection in the SI literature is also found in the citation pattern, namely between the initial and the recent SI literature. It might be explained by a strong focus to very specific topics covered in the first phase of SI research e.g. on social capital as a key driver for local adoption of SI practices (Bebbington, 1997) or suggesting a holistic SI agenda but for a very specific system (Balasubramanian et al., 2007). Afterwards the discussion substantially broadened (Wezel et al., 2015) which might explain why authors have very different perceptions on SI. Since overarching papers for the internal SI literature are missing, this paper's contribution to advance the topic is to identify and describe unifying elements and to tie up loose ends (proposition 1).

6.2. Conceptual framework of SI

The systematisation of SI in the proposed conceptual framework pursues a bottom-up approach with a strong emphasis on the actual SI praxis (proposition 2). In this way, we diverge from the theoretical delineations of partly competing ideas such as sustainable intensification, ecological intensification, climate-smart agriculture or agroecology (e.g. as done in Campbell et al., 2014; Wezel et al., 2015). A large portfolio of SI practices exists because SI does not privilege any type of implementation (Suhardiman et al., 2016). Moreover, the

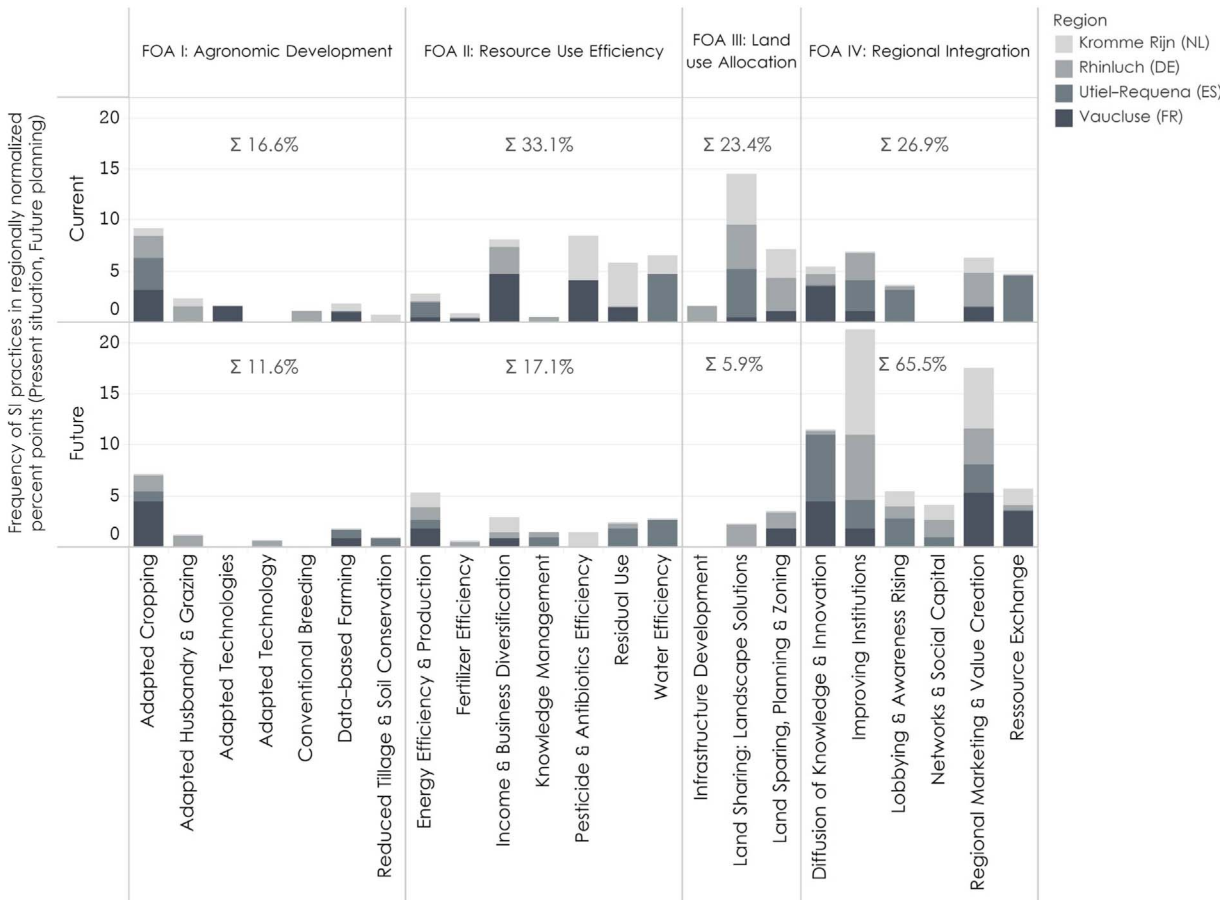

Fig. 7. Current and future SI practise in four European case studies determined in a participatory stakeholder process. Bars display the frequencies of proposing a SI approach in the current and future situation. Regional frequencies are weighted to represent regional results equally by normalizing the absolute sum of all frequencies in a situation to 100 adjusted in such a way that each region makes up for 25 points in total in the frequency index. Approaches not mentioned by stakeholders: Biotechnology and Genetic Engineering (FoA I); Adapted Livestock Fodder; Soil Management Systems; General Resource Efficiency (FoA II).
Source: Own representation.

contexts in which SI practices are applied differ widely, ranging from the intensification of underperforming agricultural systems (Mueller et al., 2012) to the redesign of intensive systems in order to decrease their environmental pressure (Robinson et al., 2015). In contrast to terminology influencing the acceptance of concepts (Godfray and Garnett, 2014), starting from implementation is relatively neutral.

The framework integrates a literature that has shown to be relatively specialised. Thus it can guide the selection of suitable SI practices when designing local solutions (Buckwell et al., 2014; Wittman et al., 2016). A closer look at the four described FoA shows that many practices are already commonly implemented by farmers and investigated in research. Adapted cropping practices such as legumes and intercropping, for instance, have been discussed as means for sustainable agriculture for many years. Institutional progress in general is seen as a key issue for agricultural and rural development (Dorward et al., 2004).

Considering the framework from a holistic perspective, the novelty of SI rather lies in the possibilities of strategically coupling different fields of action, approaches and practices. The key challenge here is the identification and adoption of suitable SI practices by relevant actors. The adoption of new SI practices on the farm is a long and dynamic process depending on risk preferences, neighbourhood effects, peer-group learning and past innovation experiences (Sauer and Zilberman, 2012). Drivers for SI have farm-type dependent effects (Firbank et al., 2013). Coordinated efforts, collective action and communication are required as soon as multiple actors are engaged and practices must be applied on larger scales than the single farm (Ostrom, 2010).

Several reasons add to the fact that those SI practices involving decisions of multiple actors, namely in the fields of 'Land Use Allocation' (FoA III) and 'Regional Integration' (FoA IV), are relatively underrepresented in the literature. The complexity of governance and planning mechanisms do not lend themselves to easy analysis. They are not easily quantifiable and they take more time and coordination to study especially if societal actors are included in the research (Mauser et al., 2013). Thus, this kind of studies might be less commonly carried out. However, these authors might also be more reluctant to connect their studies to the disputed SI literature (Godfray and Garnett, 2014).

6.3. Regional applicability and particularisation

SI practices depend on regional settings, historical developments and current land use practices and, thus, necessarily have distinct shapes in different places and agricultural systems (Barnes and Poole, 2012; Buckwell et al., 2014). Local solutions depend on both environmental and socio-economic conditions (Scherer et al., 2018). In all four cases in which the framework was applied our results revealed holistic solutions covering all four FoA depending on the problem context and local knowledge (proposition 3).

The communication process between regional actors played a crucial role. It revealed priorities, rationales of thought and action on the part of land users, and shed light on conflicts. Prior research has shown that, if individuals can have discussions on an informed basis, with knowledge of who else is affected by the same problem and learn about each other's positions in a neutral atmosphere, reciprocity and trust-building can be enabled and room for common actions and solutions discovered (Ostrom, 2010). Regional knowledge and experience have been identified early (Bebbington, 1997) and are about to be rediscovered (Wittman et al., 2016; Garibaldi et al., 2017) as crucial for progress towards SI. An important point that may help to resolve criticism of SI is that regional acceptance and compromise is needed in order to implement SI practices and thus a generic framework of SI can be value-neutral and must not exclude certain practices in advance.

In its mixed-method approach, this study entails a methodological advancement. It integrates a systematic literature review with a qualitative case study approach including the knowledge and expertise of regional stakeholders. Thus a structured, generic procedure is matched with particularised, problem-specific results. The scientific and practical knowledge can be linked and compared. For SI covering a broad range of topics and disciplines, this is a promising approach to synthesize understanding, as case studies are especially useful when the phenomenon under investigation is complex and regional particularisation is required (Lokke and Sorensen, 2014). In-depth case studies and participatory processes are needed to understand SI from a system perspective and to pursue reality checks (Wittman et al., 2016). Unlike the scientific literature, practitioners see a clear need for future action on the landscape scale, namely in FoA IV 'Regional Integration'. Important issues raised are exchange, networks, trust, mutual learning and coordinated action. Thus a gap between science and practice seems to exist that needs to be addressed.

7. Conclusions

With this systematic literature review, we have developed a conceptual framework of SI that enables action-based access to a heterogeneous field of research. In a structured way, the framework defines the scope of SI, contributes to a holistic understanding and offers a mode to unify diverging perspectives. A broad portfolio of SI practices and detailed assessments of single SI approaches exist. However, little effort is devoted to study SI as an objective requiring integrated practices, coupling the farm and landscape scales and different fields of action. This also requires addressing decision-making structures of various agents on different scales. In order to pursue a future-oriented SI research agenda, interdisciplinary cooperation is needed to address SI from a holistic perspective. The focus should be on the implementation of approaches paying attention to the behavioural rationales of farmers and land users. In many contexts, coordinated and collective decision-making will be required which is facilitated by local discussion and coordination. The proposed framework has proved able to support and guide regional discussions, integrate local knowledge on fruitful SI practices and allow different stakeholders to communicate on solutions for region-specific problems involving different views and demands. In doing so, practitioners identified the need for regional coordination, integrated solutions and common action; now research has to follow suit.

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