Chapter 5
Agroecological Principles from a Bibliographic Analysis of the Term Agroecology

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Abstract Agricultural developments over the previous half-century have highly increased food, feed and fiber production. Yet, global food output and distribution still falls short of feeding the world with unintended harm to the environment and society. Agriculture requires new approaches that meet the challenges of sustainable and equitable food production. One prevailing alternative, agroecology, is an approach that promotes environmental conservation, ecosystem health and social equality in the global food system. However, the field of agroecology remains disjointed by a number of working definitions and conflicting agendas. Lack of a clear definition of the term can lead to misuse or overgeneralization that hinders effective dialog, collaboration, and development of the discipline.

We conducted a literature review to determine trends in current usage of the term 'agroecology' and to offer an approach to developing a unified agroecological framework. Our findings suggests that diverse agendas in agroecology can be unified through the fundamental principles of systems thinking, resilience, biodiversity, and production. We found that the agroecological literature continues to grow at a rapid rate. Agroecological practices are discussed more often than principles, though almost half of publications already use the term systems approach. Biodiversity and resilience are not as well represented in the literature, though resilience is increasingly used in recent papers. The diverse perspectives and agendas encompassed by agroecology are a strength of the discipline when communicated within a clear and open dialog. Improving cohesion among agroecologists through a focus on defining foundational principles will broaden the credibility of agroecology in science and public opinion.

Keywords Agroecology • Agroecosystem • Systems approach • Resilience • Biodiversity • Science communication

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5.1 Introduction

Agriculture faces many challenges globally. The food supply must support a rising population and an increasing demand for high-calorie foods (Snapp and Pound 2008; Tilman et al. 2011). Agriculture currently uses an abundance of non-renewable resources to maximize production that can cause negative impacts to the environment and society (Cassman 1999; Altieri 2002; Rosegrant and Cline 2003). Intensive cropping systems often rely on high rates of pesticides and fertilizers. These practices persist despite the risk of pest resistance and nutrient loss that requires farmers to continually increase inputs to maintain crop productivity (Matson et al. 1997; Perfecto et al. 2009; Davis et al. 2012). Once harvested, as much as 70 % of the food calories produced in our agricultural system are used for animal feed or biofuel, with even more lost as waste products (Cassidy et al. 2013). Urban centers around the world are increasingly isolated from agricultural lands leading to a populous less connected to where and how their food is grown (Loomis and Connor 1992). The result has been a general erosion of a cultural relationship to healthy fresh food, reduced participation in food production and preparation, and an increase in diet related disease (Popkin 2011; Popkin et al. 2012).

Over the years, there have been increasing calls for new approaches to agriculture to help solve these challenges. Agroecology emerged as one prevailing alternate approach that considers ecology, evolution, and social equality as the foundation for evaluating farming practice and food distribution success (Altieri 1987; Snapp and Pound 2008; Wezel et al. 2009; Weiner et al. 2010; Francis and Porter 2011). The concept of agroecology has developed over the course of nearly a century across many related disciplines and increasingly has entered common usage (Wezel et al. 2009). Since the term's first use, many divergent definitions and philosophies have evolved (Altieri 1987; Wezel et al. 2009; Tomich et al. 2011). Contradictory understandings of agroecology among researchers, practitioners, political activists, and policy makers result in unnecessary suspicion and conflict that raise barriers to the effective development and implementation of the discipline (Rosset and Altieri 1997; Dalgaard et al 2003; Oenema et al 2003; Phelan 2009; Altieri 2012).

A unified agroecological framework will improve the dialog among the disparate groups interested in the intersection of food production, sustainability, and social justice and cohesively work to face the modern challenges of agriculture (Wezel et al. 2009; National Research Council 2010; Tomich et al. 2011). In this paper we present a literature review that surveys the unique aspects and uses of the term agroecology and the fundamental unifying principles of the discipline. Our review suggests the field can build cohesion by focusing on principle over practice to facilitate meaningful dialog among scientists and practitioners and broaden the credibility of agroecology in science and public opinion.

5.1.1 History and Background

Agroecology and its principles first appeared in the late 1930s as a scientific discipline that combined agronomic and ecological methods in research on soil health and crop production (Wezel et al. 2009). Early agroecology was influenced by a debate on how to view and interact with an agricultural system and its parts (Steiner 1924; Howard 1940; Northbourne 1940). Sir Albert Howard is credited with an approach to farming that recognizes the soil as a complex evolving biological system, a perspective influenced by the philosophy of Charles Darwin (Conford 2001). Howard's views were counter to the prevailing 'Law of the Minimum' approach formalized by Justus von Leibig. The 'Law of the Minimum' defines soil fertility as limited by a suite of essential elements required for plant growth (von Liebig 1840). The result was a general shift in focus away from recycling organic materials that maintain soil fertility and health to a focus on replacing individual essential elements in readily available form. Deficiencies in soil fertility were now easily and cheaply corrected with the specific limiting element while problems with pests were controlled with new biocides.

Despite the phenomenal success of the modern agriculture methods in increasing farm productivity while reducing farm labor, there was growing concern among scientists, farmers and the general public that unforeseen consequences were negatively affecting both the wider environment and society at large. Widespread soil loss, pollution of water bodies, loss of biodiversity, the erosion of rural communities and a general decline in public health were increasingly seen as the direct result of an increasingly industrialized food system (Altieri 1987; Perfecto et al 2009; National Research Council 2010). The search for alternatives arose among scientists, farmers and the general public. Many of these new agendas allied themselves with the ideas of agroecology, using and defining the term in subtly different ways.

While discrete boundaries in usage do not always exist, we find it useful to break agroecology into four main categories. Simultaneously, agroecology is (1) an ecologically based systems research approach, (2) an agricultural design that mimics nature, (3) an agricultural practice implemented to achieve sustainability, and (4) a socio-political movement that promotes social and environmental integrity in the food system. These categories converge to facilitate a system of resilient agriculture that minimizes external resource requirements while producing an adequate supply of food and fiber and preserving social and environmental integrity.

5.1.2 Defining Terms and Concepts

5.1.2.1 The Current Framework

The current agricultural framework strives to maximize yields with the efficient use of resource inputs (Jackson 1997). Agricultural systems are improved through use of a reductionist approach. Reductionist research is extremely effective in identifying mechanisms that improve upon expert knowledge, dubbed the industry standard or best management practice. The components of agriculture split into an open system with discrete inputs and outputs as a result of the focus on underlying mechanisms and simple systematic levers (Altieri 1987). The open system is maintained to function at the greatest efficiency and advanced to use fewer inputs per unit output. The current framework misses potential system-wide impacts of its modular design, such as environmental degradation from waste products and sociological disruptions in health and economy (Matson et al 1997; Cassman 1999; Phelan 2009).

The current agriculture framework considers increased production and economic gains as the primary goal. Decision-making by the farmers is heavily constrained by available markets, large agribusinesses that monopolize agricultural inputs, such as seeds or fertilizer, and by food processing industries that demand unblemished uniformity in large quantities (Howard 2009). Farmers are forced to increase production to meet loan payments or leases on land from local elites or foreign investors (Snapp and Pound 2008; Vandermeer 2011). The remainder of the population is disconnected from their food source and the great challenges facing modern agriculture seemingly content to pay a smaller percentage of their earnings for food than ever before (National Research Council 2010).

5.1.2.2 The Agroecosytem Concept

The term agroecosystem can be thought simply as an agricultural field, farm or region. It describes a coherent agricultural unit, the boundaries of which include aspects normally outside the primary agricultural interests of productivity and profitability including environmental, biological, economic and sociological processes. Diverse biological processes and ecological relationships drive a healthy agroecosystem that expresses long-term maintenance of the biological, physical, and social qualities of the farmland. Model agroecosystems support adequate farm production, regulate and balance the flow and timing of nutrients, actively build healthy soils, maintain and regulate species interactions, conserve biodiversity, and adapt to dynamic conditions (Okey 1996; Altieri 1999; National Research Council 2010; Lemaire et al. 2014).

These healthy qualities of an agroecosystem, called 'ecosystem function', provide additional benefits as a result of an agroecological approach (Swift and Anderson 1994). With strong ecosystem function, external inputs can be applied sparingly and are efficiently recycled (Oenema et al 2003; Gliessman 2007; Schramski et al. 2011). Production driven economic considerations may require increased energy and resource demands to maintain yields, but then ecosystem function can be leveraged to the benefit of other economic returns (Reganold et al. 2001). Ecosystem function and the resulting goods and services can be maximized when considering the agroecosystem as a whole (World Commission on Environment and Development 1987; Costanza et al. 1997; Klein and Sutherland 2003; Millennium Ecosystem Assessment 2005).

Agroecosystem boundaries can be drawn at a broad range of scales (e.g., soil, plant, plant-pest, field, farm, region, food system) and describe the spatial and temporal context of practical recommendations in agroecology (Levin 1992; Altieri 2012). Some agroecologists seek to understand the nutrient cycles and biotic interactions in the soil defining their agroecosystem boundaries at relatively small scales (Lundquist et al 1999; Arshad and Martin 2002), while others define boundaries at the intermediate farm or regional level (Reganold et al. 1987; Reganold et al. 1993; Drinkwater et al. 1995; Letourneau and Goldstein 2001; Reganold et al. 2001). Still, others work at the level of the food system, including economic and sociological processes (Gliessman 2007; Wezel and David 2012). The findings from these multiple scales must then be linked and synthesized to be sure comprehensive knowledge is available for successful agroecological outcomes and recommendations. Overall sustainability in agriculture can only come from understanding the interactions of all components of the food system.

5.1.2.3 Agroecology I: A Scientific Research Approach

The first definition of 'agroecology' is a rigorous systems approach to compare and evaluate the characteristics of agricultural production systems, such as productivity, profitability, and broader impacts on the environment and society. The agroecological research approach explores linkages among physical, chemical, biological, and social components of an agricultural system across space and time (Jackson 1997; Klein and Sutherland 2003; Doré et al. 2011). Alternative modern farming systems developed through the agroecological research process integrate traditional farming, modern farming and improved management practices and technologies to build and maintain a healthy agroecosystem (Matson et al. 1997; Altieri 2002).

Agroecologists use complex systems analysis tools with detailed observations to evaluate agroecosystems and describe successful management strategies (Lockeretz et al. 1981; Drinkwater 2002; Mäder et al. 2002; Verma et al 2005; Reganold et al. 2010; Doré et al. 2011; Davis et al. 2012). Some ideas and tools are integrated from other related scientific fields, like evolutionary biology (Weiner et al 2010) or physics (Deng et al. 2012). Although many systems studies do not allow for the direct identification of factors responsible for the observed relationships, a strength of the current reductionist agricultural research model, they can effectively compare differences between complex biological systems. Systems can be identified at any scale from soil to food system, though many of the analytical tools perform better over large spatial and temporal scales and benefit from long-term research programs (Bawden 1991; Drinkwater 2002; Robertson et al. 2008; Hufnagl-Eichner et al. 2011). Such research programs build understanding of agroecosystem processes to improve the performance of the farm as a whole.

5.1.2.4 Agroecology II: An Agricultural Design

Agroecology is also defined as a method of agricultural design that is informed by observations of traditional farming systems, natural ecosystems and agroecological theory. The extreme examples of agroecosystems under this definition look more like natural ecosystems than farms, but the term is most often used in this context to describe agroecological systems that are moving in the direction of greater complexity and resilience.

As the design of agroecology developed to mimic naturally occurring ecological systems and traditionally sustainable farming systems, a number of additional terms arose to describe an agroecological farming system, including biological agriculture, sustainable agriculture (Hahlbrock 2007; Pretty 2008), organic agriculture (Zehnder et al 2007; Vogt 2007), biodynamic agriculture (Reeve et al. 2011), natural systems agriculture (Glover et al. 2010; Franzluebbers et al. 2014), agroforestry (Huxley 1983; Anderson and Sinclair 1993), restoration agriculture (Shepard 2013), permaculture (Ferguson and Lovell 2014), and traditional agriculture (Altieri 2002; Perfecto et al. 2009). All of the types of farming listed can be considered 'agroecology' under the definition of an agricultural design and share the goal to intensify ecological processes (Altieri 1999; Pretty 2008; Doré et al. 2011). Components of current industrialized agriculture can also be viewed as an agroecological design, especially when incorporating natural processes occurring in ecological systems (Cassman 1999; Cassman et al 2002; Fuhrer 2003; Zehnder et al 2007; Wezel et al. 2014).

Often designs are then communicated broadly through the description of an agroecological practice, a slight permutation of this second term that we discuss in the following section.

5.1.2.5 Agroecology III: An Agricultural Practice that Meets the Highest Standard in Sustainability

Agroecology describes an agricultural system or set of practices that is deemed sustainable. Farmers expect scientists to recommend practices suitable to their area, and they tend to be less concerned with abstract, nuanced principles behind the practical decision. This need for concrete advice encourages researchers to focus on practices, especially as some may have broad applicability and are easily replicable. Practices generated from the agroecological framework motivate further research and can provide well-supported recommendations to the public if used within appropriate contexts (Uphoff 2002; Wezel et al 2014).

Agroecological practices are the building blocks and spokesmen of the agricultural approach but they can lead to misunderstood recommendations and inappropriate adoption if overgeneralized. For example, the benefits of organic fertilizer for soil health are likely universal, but the question of how much to apply is very site specific. As with any fertilizer, improper application can negatively affect the environment, cause nutrient imbalances, or reduce yield (Mäder et al 2002). Cover crops can be extremely beneficial in many situations but may utilize scarce soil water reserves or confer negligible ecosystem benefit such as weed suppression (Smith et al 2014). Increasing biodiversity more generally can promote pest and disease control but the effectiveness is often very site-specific (Ratnadass et al 2012). The over generalization of agroecological recommendations is likely to remain an ongoing challenge, but greater awareness of the issue will help avoid the impression that certain practices represent a universal solution.

The appropriate use of agroecology as a 'practice' must include the allowance for a developmental process towards sustainability; otherwise, it erroneously assumes that the recommended practice will achieve sustainability regardless of context. This extreme usage implies that a specific type of farming system or set of practices is the most sustainable option regardless of potential system-specific, socio-economic, or environmental conditions. This assumed result easily leads to misuse or overgeneralization. A preferred perspective would refer more loosely to a developmental process that is designed to move in the direction of the highest standard but has yet to reach the goal.

It is exceedingly important to be precise when using 'agroecology' as a descriptor of the highest standard of practice and resulting agroecosystems. Very few, if any, truly sustainable and equitable agroecosystems exist where this would be appropriate. Indeed, agroecological systems are tremendously diverse in outward appearance and management practice, but share a common set of ecological and socioeconomic principles. Unless we are careful to define our terms, this permutation of the term 'agroecology' is very difficult to separate from the other meanings and opens us to the criticism that we are over-extrapolating and failing to appreciate the complex and context-dependent nature of agriculture.

5.1.2.6 Agroecology IV: A Socio-political Movement

Another definition of agroecology is a socio-political research and policy movement at the food-system level. This agroecology focuses on the practical application of the science of agroecology with the people as central to the system (Altieri 1987; Reijntjes et al. 1992; Chazdon et al 2009). Food production and distribution processes are linked in a complex coupled system of people and their environment, with diverse climates, cultures, and decision-making principles involved in the success of the food system.

Agroecology provides a scientific basis for a sustainable development strategy emphasizing conservation of natural resources and biodiversity through the empowerment of rural social movements (Rosegrant and Cline 2003; Perfecto and Vandermeer 2008; Snapp and Pound 2008; Wezel et al. 2009). One important goal, food security, promotes the availability, stability, and access to food (Altieri et al. 1999; Schmidhuber and Tubiello 2007). The failings of thinking purely in terms of food security have been challenged by the concept of food sovereignty, which requires social equity and the ability for consumers to have a supply of food from an ethically acceptable source (Perfecto et al. 2009; Rosset et al. 2011). The socio-political movement of agroecology advocates for the equitable and participatory approach to food production and distribution at the intersection of food security and food sovereignty.

5.2 Word Use in Agroecological Publications

We conducted a quantitative literature search in order to determine how agroecological publications are using key terms that are associated with the field. From this analysis, we address trends in the terms we describe as fundamental to the field and evaluate the overall usage of additional terms related and synonymous to 'agroecology'.

5.2.1 Methods

We searched the large academic publication database Scopus for a number of key terms. We separated the terms into four groups; primary, focal, additional, and synonyms. Our primary search returned all publications with 'agroecology' or 'agroecological' in the title, abstract, or keywords (Table S1). The searches for focal and additional terms were a subset of the primary search (Table 5.1). Focal terms correspond to the main descriptions of the term 'agroecology' in Sect. 5.1.3 and the terms we suggest for use as unifying principles. The additional terms are words strongly related to the field, but did not fit the previous groups. Synonyms are words or phrases that may be used interchangeably with 'agroecology', many listed in Sect 5.1.2.4, and were analyzed independent of the primary search (Table 5.2). We recorded the count for all publications returned in the search and the publication count per year for 1994–2014 for the primary search and 2004–2014 for the focal terms (Figs. 5.1 and 5.2). For the focal terms, we recorded the ten publications with the highest citation record (Tables S1–S9).

5.2.2 Results

The primary search ('agroecology' OR 'agroecological') returned 2722 results. This is a relatively small number of publications given the size of the database, suggesting a low representation of the field among scientific disciplines. For reference, a search for 'agriculture' returns 189,540 publications. Regardless, the publications per year are continuing to rise at a very rapid rate (Fig. 5.1; Wezel and Soldat 2009). Publication count has more than doubled each decade from 1994 to 2014 to more than 250 for three of the last 4 years.

The search for focal terms helps us determine the trajectory of the field as it relates to moving towards a unified framework. Many more publications are written about 'practice' than 'principle' (Table 5.1). Use of the term 'practice' continues to rise every year while 'principle' has minimal fluctuation (Fig. 5.2). Among the focal terms that define our 'agroecology' term, 'research' is much more represented than 'design' and 'movement'. This may largely reflect our use of an academic publication database, though we would expect 'design' to be similarly represented as

Table 5.1 Search term totals for publications including *focal terms* and *additional terms*

Term	Count
– *Focal terms*	
agroecolog –y/-ical	2722
~ principle	165
~ practice	580
~ research	620
~ design	231
~ movement	97
~ systems	1171
~ biodiversity	293
~ resilience	48
– *Additional terms*	
~ production	955
~ sustainable	486
~ organic	413
~ conservation	362
~ biological	283
~ farming systems	243
~ traditional	235
~ food security	142
~ agroforestry	115
~ food systems	56
~ restoration	47
~ food sovereignty	40
~ systems approach	21
~ communication	19
~ systems research	13
~ natural systems	13
~ mixed farming	13
~ equity	10
~ systems thinking	5
~ ecological intensification	5
~ biodynamic	4
~ silviculture	3

Table 5.2 Search term totals for publications including *synonymous terms*.

Term	Count
– *Synonymous terms*	
agroforestry	6016
sustainable agriculture	5385
silviculture	5189
organic agriculture	1869
traditional agriculture	990
mixed farming	772
conservation agriculture	642
biological agriculture	79
biodynamic agriculture	42
restoration agriculture	22
natural systems agriculture	7

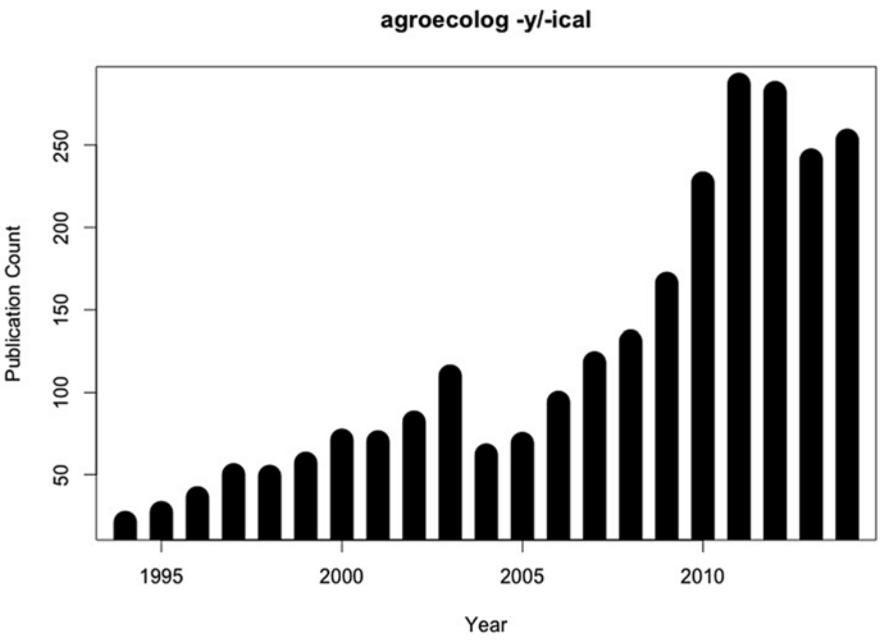

Fig. 5.1 Timeline of agroecological publications from 1994 to 2014

'practice'. Of our focal terms that relate to our proposed unifying principles, 'systems' is most represented, being used in almost half of all the papers in the primary search. 'Biodiversity' was moderately represented and 'resilience' much less. All six focal terms continue to increase in use each year.

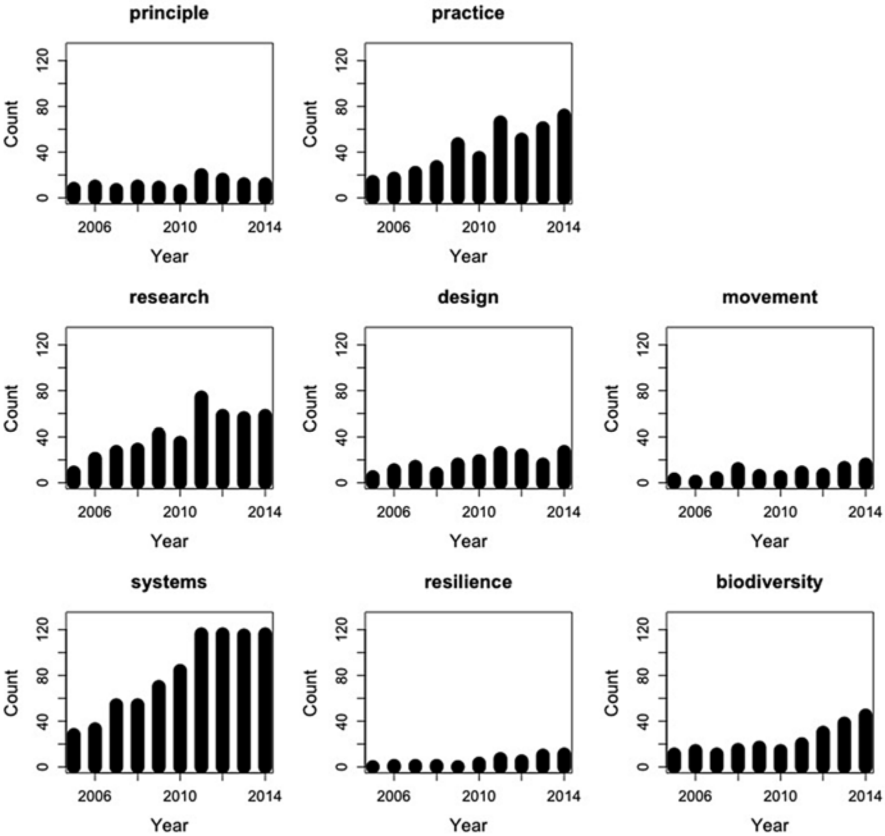

Fig. 5.2 Timeline of focal terms used in agroecological publications from 2004 to 2014

The search for additional terms, such as ‘production’, ‘sustainable’, and ‘organic’ helps us understand the use of related terms that could represent principles important for unification. Perhaps unsurprisingly, ‘production’ returned the highest number of publications used in about one-in-three publications. It returned more than double the publication results of the next two most used, ‘sustainable’ and ‘organic’, which are used in about 1:6 publications. ‘Conservation’, ‘biological’, and ‘farming systems’ are the next most frequent additional terms used in 1:8 to a little less than 1:10 publications.

We determined the rank of the most commonly used synonyms to ‘agroecology’ through an independent search of the database. ‘Agroforestry’, ‘sustainable agriculture’, and ‘silviculture’ returned more results than ‘agroecology’, with 6016, 5385, and 5189 publications respectively. ‘Organic agriculture’ (1869) and ‘traditional agriculture’ (990) were the next most used synonymous terms.

We compiled and investigated the top ten citations lists of focal terms to add further commentary on the application of terms we describe as the foundation of agroecology (Table S1–S9). We suggest these citations represent the core usage of the focal terms and identified many interesting debates occurring in the discipline. It is clear many are still working to define ecological intensification as a synonym for agroecology. 'Ecological intensification' has garnered much interest as a term, but appears very sparsely in the agroecology literature (Table 5.1). The debate between those who promote agroecological practices for incremental improvement to agriculture and those who advocate for transformational change is ongoing. In support for our focus on 'resilience', a majority of the top citations for the term were published recently unlike many of the other terms (Table S9). Many of the same publications appear under multiple search terms, suggesting the terms we offer as focal are used together by the most widely read and cited contributions to the agroecology literature. Publications appearing in multiple top ten lists are noted in the tables and received special attention to be cited in our review.

5.3 Developing a Unified Agroecological Framework

5.3.1 Guiding Principles of the Agroecology Framework

With roots in several diverse disciplines, a single definition of agroecology has remained elusive; however, the goals and defining characteristics of an agroecological approach are strikingly consistent. Broadly, the agroecology framework integrates principles of agriculture, ecology, social equity, and sustainability. By combining all four uses of the word 'agroecology', we define it as a field of study motivated to understand ecological, evolutionary, and socioeconomic principles and use them in an improvement process that sustains food production, conserves resources, and maintains social equality.

We conducted a literature search to discover emergent principles that could guide a unified agroecological framework. We propose the principles of systems thinking, production, biodiversity, and resilience as fundamental components of a unified agroecological framework. We find that agroecologists effectively place emphasis on a systems approach to agriculture and strive to integrate environmental, ecological, and socioeconomic integrity in agroecosystems (Pretty 2008). The principle of production is also already a strong component of agroecology; though, the relative importance of production is one of the major rifts among scientists in the field. Indeed, the problems associated with an emphasis on production and bottom line can be mitigated through a systems thinking approach to agriculture and a greater emphasis on resilience and biodiversity, currenly lacking in the field.

We encourage greater emphasis in agroecology on the principle of resilience. The term resilience is used in many highly cited recent publications to describe food systems that rely on ecosystem function, system regeneration, biological diversity, and equitable participation (Fig. 5.2 and Table S9). Resilience can be measured in relation to sustained production, overall agroecosystem health, and the system's ability to respond to distress over long time periods (Altieri 1987; Okey 1996; National Research Council 2010). External disturbances that might stress an agroecosystem include drought, disease, pest outbreaks, economic recession, and market fluctuations. Shocks to the system from external disturbances can cause major disruption in the functioning of simplified farming systems that rely heavily on inputs. More complex agroecosytems may recover quickly and require less intervention following distress (Altieri 1987; Franzluebbers et al. 2014).

Agroecologists should also unviersally emphasize the principle of biodiversity. High species diversity may lead to self-regulation of pests and resource regeneration in an agroecosystem (Matson et al. 1997; Swift and Anderson 1994; Altieri 1999; Shea and Chesson 2002; Vandermeer 2011). It has been demonstrated that increased biodiversity in the soil improves water use, nutrient uptake, and disease resistance of crop plants (Brussaard et al. 2007; Franzluebbers et al. 2014). Crop diversity, in both space and time, can improve overall biomass production in the system and reduces required inputs (Tilman et al. 2001; Davis et al. 2012). It may be equally important to consider the composition of a biodiverse agroecosytem in addition to the species count to ensure favorable production and pest suppression (Ratnadass et al 2012). Overall, we find biologically and culturally diverse farming systems promote resilient, sustained, and equitable food production.

5.3.2 Building Cohesion with a Unified Agroecological Framework

In many ways the field is converging on a standard approach to innovation and implementation that can rapidly progress towards the development of new and effective agroecological systems (Fig. 5.3). In other ways, a diverse set of goals and agendas diminish the effective communication and credibility of the discipline (Rosset and Altieri 1997; Dalgaard et al 2003). We encourage further dialog regarding a decision-making strategy that would develop a standard set of principles fundamental to unify agroecology.

The ultimate goal of the agroecological framework is to develop sustainable agricultural systems through an understanding of complex ecological processes and prioritizes resource conservation and social equity. Through decisions supported by an agroecological framework, agriculture would strive to feed the world (Tilman et al. 2011), provide better nutrition (Brandt et al. 2011), restore ecosystem processes (Drinkwater et al. 1998), maintain biodiversity (Perfecto et al. 2009), adapt to climate change (Fuhrer 2003; Schmidhuber and Tubiello 2007) and foster healthy communities (Snapp and Pound 2008). However, very few agricultural systems meet all of these goals, and even more fall short as the food product moves through the processing and distribution chain (Cassidy et al. 2013).

For widespread behavioral and institutional shifts, agroecologists must facilitate dialog that promotes the development of productive agricultural systems that are economically viable, environmentally safe, resource conserving and socially just (Chazdon et al 2009; National Resource Council 2010). Future dialog must address the diverse agendas among agroecologists and misconceptions that have emerged among agroecologists and the public. The goal of the dialog should be to establish

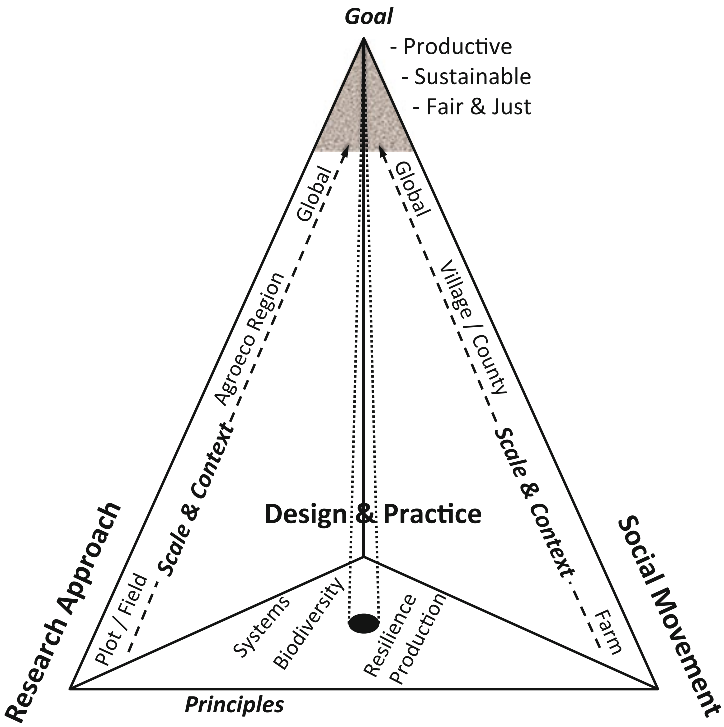

Fig. 5.3 Conceptual diagram of the unified agroecological framework. The framework builds a foundation from the major facets of the discipline (research, design & practice, sociological movement) and the major principles (systems, biodiversity, resilience, production). The agroecological framework develops its systems along various scales and contexts to move towards the goal of the ideal agroecological system

the core values and principles of the discipline and strive to place those concepts at the forefront of the conversation. The dialog has faced a number of barriers from agricultural scientists, farmers, and the public, but many promising shifts are taking place.

One barrier that must be addressed is the idea agroecology has become synonymous with a faction firmly against the trajectory and goals of conventional industrialized agriculture. As a consequence, agroecology can be misrepresented as immediately sustainable agriculture or practice that is inherently superior and mutually exclusive to the current conventional system, as in our third term (Sect. 5.1.2.5). In reality, very few agroecological systems are entirely sustainable given the current global food production and distribution system. They benefit from context-dependent integration of conventional and agroecological practices to work towards achieving sustainability (Cassman et al 2002). It is insufficient to mimic an existing practice or adopt a recommendation without considering the environmental and social context of the new location. Rather than defining agroecology as a prescriptive list of practices that may or may not be well suited to any given setting, it is important to describe it as a process and set of principles to move towards sustainable agriculture.

Another barrier is the trade-off between system-wide resilience and the stability of a single entity. Biodiverse agroecosystems are resilient as a whole, but their component parts, such as the commodity crop, might fluctuate widely within the overall system stability (Fischer et al. 2006; Tilman et al. 2006; Ratnadass et al 2012; Sabatier et al. 2013; Lemaire et al. 2014). This fluctuation of target crops poses an ecological challenge for the evolution of biodiverse agroecosystems (Weiner et al. 2010). Economically, farmers must have access to diversified markets so that agricultural production is not limited to a single commodity whose production may fluctuate with climatic and biological shifts, or whose price may fluctuate with the markets (Kleijn and Sutherland 2003). When farmers do rely on one commodity crop, they create simpler agroecosystems that compromise diversity in an effort to improve production stability to meet market demands (Tilman et al. 2006; Sabatier et al. 2013). Resilience of the whole agroecological system is important, and tradeoffs are sometimes necessary if we value the economy, the environment, and society equally.

We urge agroecologists to emphasize general principles of resilience and biodiversity aimed at improving productivity, environmental conservation, economic viability, and social equity. From a systems approach based on foundational principles, context-dependent solutions will arise using the breadth and depth of agroecological knowledge and application. Our unified agroecological framework encourages increased farmer and consumer demand for information about growing and distributing food that must be met with a clear and open dialog.

5.4 Summary and Conclusion

Agroecology emerged in the 1930s alongside early agronomic research and first diverged during a debate over whether soil should be treated as a simplified mix of plant growth media or as a complex biological agroecosystem. The current simplified agricultural framework focuses primarily on production and fails to adequately feed the world while also causing unintended harm to the environment and society. The agroecological approach includes environmental, biological, economic and sociological processes within a defined set of agroecosystem boundaries.

Agroecology has developed as a field and as a descriptive term with a myriad of uses that can be grouped into four main descriptions: (1) a rigorous systems research approach that compares and evaluates the impacts and improvements of agriculture on the natural and socio-economic environment, (2) a method of agricultural design that is informed by observations of traditional farming systems, natural ecosystems, and agroecological theory, (3) a moniker for an agricultural practice that has achieved the highest measure of sustainability, often used erroneously out of context, and (4) a socio-political research and policy movement that focuses on the broad effects agricultural choices have on people.

We conducted a literature review of the academic literature that suggests agroecologists can build cohesion through emphasis on systems thinking and the integration of environmental, ecological, and socioeconomic principles in agriculture, such as resilience, biodiversity and production. Future research could expand on our analysis to include the agroecological dialog in trade and popular literature also. Publications in the field of agroecology continues to increase at a rapid rate and can improve quality of communication through a deliberate use of principles and clear terms. Many goals and characteristics of an agroecological approach are strikingly consistent that can build cohesion and unification in the discipline. We propose the principles of systems thinking, resilience, biodiversity and production as fundamental components of a unified agroecological framework. Agroecology aims to produce sufficient agricultural products in a system that emphasizes biological processes and ecological relationships, limits external inputs and maximizes nutrient recycling, and gives equal consideration to the economy, the environment, and the society.

Agroecology has a long history influenced by several fields of study and continues to promote a rapid increase of interest and use. Interdisciplinary teams of researchers and visionary farmers use an agroecological framework to promote a systems approach to developing resilient agroecosystems that produce food, conserve resources, and provide a fair livelihood for practitioners of agriculture in the long term. However, subtle permutations of the understanding of agroecology among researchers, farmers and the public have led to communication barriers that impede the field's development. This multitude of meanings requires us to define our terminology precisely. As we move forward, we must emphasize the principles that define an agroecological framework in order to develop a sustainable farming and food system. To promote understanding among disciplines, we urge agroecologists and their colleagues to clearly describe their work within the broader context of agroecological definitions, as well as to highlight the relevant principles and constraints to their particular system.

An agroecological framework uses a systems approach to feed the world that improves resilience and diversity in the economy, environment, and society. While this simplified framework is broad in scope and based on general ecological principles, we realize that developing agroecosystems is very complex and involves site-specific decisions. Indeed, the agroecological framework encourages this diversity in systems and solutions moving toward a sustainable agricultural future.

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Supplementary Tables

Table S1 Top ten citations for the search term ‘agroecology’ OR ‘agroecological’

Title	Author	Year	Journal	Citations
[a]Agricultural intensification and ecosystem properties	Matson PA, Parton WJ, Power AG, Swift MJ	1997	Science	943
[a]Soil fertility and biodiversity in organic farming	Mäder P, et al.	2002	Science	842
[a]How effective are European agri-environment schemes in conserving and promoting biodiversity?	Kleijn D, Sutherland WJ	2003	Journal of Applied Ecology	624
[a]The ecological role of biodiversity in agroecosystems	Altieri MA	1999	Agriculture, Ecosystems and Environment	593
[a]Agroecosystems, nitrogen-use efficiency, and nitrogen management	Cassman KG, Dobermann A, Walters DT	2002	Ambio	385
[a]Ecological intensification of cereal production systems: Yield potential, soil quality, and precision agriculture	Cassman KG	1999	PNAS	366
[a]Agroecosystem responses to combinations of elevated CO_2, ozone, and global climate change	Fuhrer J	2003	Agriculture, Ecosystems and Environment	244
[a]Global Food Security: Challenges and Policies	Rosegrant MW, Cline SA	2003	Science	215
[a]Annual carbon dioxide exchange in irrigated and rainfed maize-based agroecosystems	Verma SB, et al.	2005	Agricultural and Forest Meteorology	208
[a]Agricultural sustainability: Concepts, principles and evidence	Pretty J	2008	Philosophical Transactions of the Royal Society B: Biological Sciences	200

[a]Denotes publication included in multiple top ten lists

Table S2 Top ten citations for the search term ‘principle’

Title	Author	Year	Journal	Citations
[a]Agricultural sustainability: Concepts, principles and evidence	Pretty J	2008	Philosophical Transactions of the Royal Society B: Biological Sciences	200
[a]Biodiversity conservation in tropical agroecosystems: A new conservation paradigm	Perfecto I, Vandermeer J	2008	Annals of the New York Academy of Sciences	146
[a]Farming for the future: an introduction to low-external-input and sustainable agriculture	Reijntjes C, Haverkort B, Waters-Bayer A	1992	*Farming for the future: an introduction to low-external-input and sustainable agriculture*	132
[a]Agroecology: The ecology of food systems	Francis C, et al.	2003	Journal of Sustainable Agriculture	85
SSR and pedigree analyses of genetic diversity among CIMMYT wheat lines targeted to different megaenvironments	Dreisigacker S, et al.	2004	Crop Science	69
[a]Facing up to the paradigm of ecological intensification in agronomy: Revisiting methods, concepts and knowledge	Dore T, et al.	2011	European Journal of Agronomy	68
The role of the concept of the natural (naturalness) in organic farming	Verhoog H, Matze M, Van Bueren EL, Baars T	2003	Journal of Agricultural and Environmental Ethics	62
[a]The greening of the “barrios”: Urban agriculture for food security in Cuba	Altieri MA, et al.	1999	Agriculture and Human Values	57
Communicating complexity: Integrated assessment of trade-offs concerning soil fertility management within African farming systems to support innovation and development	Gillet KE, et al.	2011	Agricultural Systems	52
Plant species diversity for sustainable management of crop pests and diseases in agroecosystems: A review	Ratnadass A, Fernandes P, Avelino J, Habib R	2012	Agronomy for Sustainable Development	49

[a]Denotes publication included in multiple top ten lists

Table S3 Top ten citations for the search term 'practice'

Title	Author	Year	Journal	Citations
[a]Agroecosystems, nitrogen-use efficiency, and nitrogen management	Cassman KG, Dobermann A, Walters DT	2002	Ambio	385
[a]Annual carbon dioxide exchange in irrigated and rainfed maize-based agroecosystems	Verma SB et al.	2005	Agricultural and Forest Meteorology	208
[a]Agricultural sustainability: Concepts, principles and evidence	Pretty J	2008	Philosophical Transactions of the Royal Society B: Biological Sciences	200
Identifying critical limits for soil quality indicators in agro-ecosystems	Arshad MA, Martin S	2002	Agriculture, Ecosystems and Environment	183
[a]Approaches and uncertainties in nutrient budgets: Implications for nutrient management and environmental policies	Oenema O, Kros H, De Vries W	2003	European Journal of Agronomy	182
Evaluation of the environmental impact of agriculture at the farm level: A comparison and analysis of 12 indicator-based methods	Van Der Werf HMG, Petit J	2002	Agriculture, Ecosystems and Environment	163
Rapid response of soil microbial communities from conventional, low input, and organic farming systems to a wet/dry cycle	Lundquist EJ, Scow KM, Jackson LE, Uesugi SL, Johnson CR	1999	Soil Biology and Biochemistry	160
Soil health and global sustainability: Translating science into practice	Doran JW	2002	Agriculture, Ecosystems and Environment	147
Determinants and effects of income diversification amongst farm households in Burkina Faso	Reardon T, Delgado C, Matlon P	1992	Journal of Development Studies	138
[a]Farming for the future: an introduction to low-external-input and sustainable agriculture	Reijntjes C, Haverkort B, Waters-Bayer A	1992	*Farming for the future: an introduction to low-external-input and sustainable agriculture*	132

[a]Denotes publication included in multiple top ten lists

Table S4 Top ten citations for the search term 'research'

Title	Author	Year	Journal	Citations
[a]How effective are European agri-environment schemes in conserving and promoting biodiversity?	Kleijn D, Sutherland WJ	2003	Journal of Applied Ecology	624
[a]The ecological role of biodiversity in agroecosystems	Altieri MA	1999	Agriculture, Ecosystems and Environment	593
[a]Agroecosystems, nitrogen-use efficiency, and nitrogen management	Cassman KG, Dobermann A, Walters DT	2002	Ambio	385
[a]Global Food Security: Challenges and Policies	Rosegrant MW, Cline SA	2003	Science	215
[a]Agroecology: The science of natural resource management for poor farmers in marginal environments	Altieri MA	2002	Agriculture, Ecosystems and Environment	188
[a]Approaches and uncertainties in nutrient budgets: Implications for nutrient management and environmental policies	Oenema O, Kros H, De Vries W	2003	European Journal of Agronomy	182
[a]Arthropod pest management in organic crops	Zehnder G, et al.	2007	Annual Review of Entomology	176
An overview of some tillage impacts on earthworm population abundance and diversity – Implications for functioning in soils	Chan KY	2000	Soil and Tillage Research	147
[a]Beyond reserves: A research agenda for conserving biodiversity in human-modified tropical landscapes	Chazdon RL, et al.	2009	Biotropica	135
International approach to assessing soil quality by ecologically-related biological parameters	Filip Z	2002	Agriculture, Ecosystems and Environment	121

[a]Denotes publication included in multiple top ten lists

Table S5 Top ten citations for the search term ‘design’

Title	Author	Year	Journal	Citations
[a]How effective are European agri-environment schemes in conserving and promoting biodiversity?	Kleijn D, Sutherland WJ	2003	Journal of Applied Ecology	624
[a]The ecological role of biodiversity in agroecosystems	Altieri MA	1999	Agriculture, Ecosystems and Environment	593
[a]Beyond reserves: A research agenda for conserving biodiversity in human-modified tropical landscapes	Chazdon RL, et al.	2009	Biotropica	135
Soil fertility management and insect pests: Harmonizing soil and plant health in agroecosystems	Altieri MA, Nicholis CI	2003	Soil and Tillage Research	95
Environmental benefits of conservation buffers in the United States: Evidence, promise, and open questions	Lovell ST, Sullivan, WC	2006	Agriculture, Ecosystems and Environment	86
[a]Agroecology: The ecology of food systems	Francis C, et al.	2003	Journal of Sustainable Agriculture	85
[a]Facing up to the paradigm of ecological intensification in agronomy: Revisiting methods, concepts and knowledge	Dore T, et al.	2011	European Journal of Agronomy	68
Object-based crop identification using multiple vegetation indices, textural features and crop phenology	Peña-Barragán JM, Ngugi MK, Plant RE, Six J	2011	Remote Sensing of Environment	67
Developing incentives and economic mechanisms for in situ biodiversity conservation in agricultural landscapes	Pascual U, Perrings C	2007	Agriculture, Ecosystems and Environment	64
An agent-based simulation model of human-environment interactions in agricultural systems	Schreinemachers P, Berger T	2011	Environmental Modeling and Software	58

[a]Denotes publication included in multiple top ten lists

Table S6 Top ten citations for the search term 'movement'

Title	Author	Year	Journal	Citations
[a]Biodiversity conservation in tropical agroecosystems: A new conservation paradigm	Perfecto I, Vandermeer J	2008	Annals of the New York Academy of Sciences	146
[a]Beyond reserves: A research agenda for conserving biodiversity in human-modified tropical landscapes	Chazdon RL, et al.	2009	Biotropica	135
Agroecology as a science, a movement and a practice. A review	Wezel A, et al.	2009	Agronomy for Sustainable Development	76
Agroecology versus input substitution: A fundamental contradiction of sustainable agriculture	Rosset PM, Altieri MA	1997	Society and Natural Resources	60
[a]The greening of the "barrios": Urban agriculture for food security in Cuba	Altieri MA, et al.	1999	Agriculture and Human Values	57
The agroecological revolution in Latin America: Rescuing nature, ensuring food sovereignty and empowering peasants	Altieri MA, Toledo VM	2011	Journal of Peasant Studies	50
Organic and conventional agriculture: Materializing discourse and agro-ecological managerialism	Goodman D	2000	Agriculture and Human Values	43
Measuring farmers' agroecological resistance after Hurricane Mitch in Nicaragua: A case study in participatory, sustainable land management impact monitoring	Holt-Gimenez E	2002	Agriculture, Ecosystems and Environment	37
Traditional agroecological knowledge, adaptive management and the socio-politics of conservation in Central Sulawesi, Indonesia	Armitage DR	2003	Environmental Conservation	34
[a]The Campesino-to-Campesino agroecology movement of ANAP in Cuba: Social process methodology in the construction of sustainable peasant agriculture and food sovereignty	Rosset PM, Sosa BM, Jaime AMR, Lozano DRA	2011	Journal of Peasant Studies	31

[a]Denotes publication included in multiple top ten lists

Table S7 Top ten citations for the search term ‘systems’

Title	Author	Year	Journal	Citations
[a]Soil fertility and biodiversity in organic farming	Mäder P, et al.	2002	Science	842
[a]Agroecosystems, nitrogen-use efficiency, and nitrogen management	Cassman KG, Dobermann A, Walters DT	2002	Ambio	385
[a]Ecological intensification of cereal production systems: Yield potential, soil quality, and precision agriculture	Cassman KG	1999	PNAS	366
[a]Agroecosystem responses to combinations of elevated CO2, ozone, and global climate change	Fuhrer J	2003	Agriculture, Ecosystems and Environment	244
[a]Annual carbon dioxide exchange in irrigated and rainfed maize-based agroecosystems	Verma SB, et al.	2005	Agricultural and Forest Meteorology	208
[a]Agricultural sustainability: Concepts, principles and evidence	Pretty J	2008	Philosophical Transactions of the Royal Society B: Biological Sciences	200
[a]Agroecology: The science of natural resource management for poor farmers in marginal environments	Altieri MA	2002	Agriculture, Ecosystems and Environment	188
[a]Approaches and uncertainties in nutrient budgets: Implications for nutrient management and environmental policies	Oenema O, Kros H, De Vries W	2003	European Journal of Agronomy	182
A model for fossil energy use in Danish agriculture used to compare organic and conventional farming	Dalgaard T, Halberg N, Porter JR	2001	Agriculture, Ecosystems and Environment	178
[a]Arthropod pest management in organic crops	Zehnder G, et al.	2007	Annual Review of Entomology	176

[a]Denotes publication included in multiple top ten lists

Table S8 Top ten citations for the search term 'biodiversity'

Title	Author	Year	Journal	Citations
[a]Agricultural intensification and ecosystem properties	Matson PA, Parton WJ, Power AG, Swift MJ	1997	Science	943
[a]Soil fertility and biodiversity in organic farming	Mader P, et al.	2002	Science	842
[a]How effective are European agri-environment schemes in conserving and promoting biodiversity?	Kleijn D, Sutherland WJ	2003	Journal of Applied Ecology	624
[a]The ecological role of biodiversity in agroecosystems	Altieri MA	1999	Agriculture, Ecosystems and Environment	593
Social capital in biodiversity conservation and management	Pretty J, Smith D	2004	Conservation Biology	200
Human geography and the "new ecology': the prospect and promise of integration	Zimmerer KD	1994	Annals – Association of American Geographers	193
[a]Arthropod pest management in organic crops	Zehnder G, et al.	2007	Annual Review of Entomology	176
Global food security, biodiversity conservation and the future of agricultural intensification	Tscharntke T, et al.	2012	Biological Conservation	160
Conservation of biodiversity in coffee agroecosystems: A tri-taxa comparison in southern Mexico	Perfecto I, Mas A, Dietsch T, Vandermeer J	2003	Biodiversity and Conservation	150
[a]Biodiversity conservation in tropical agroecosystems: A new conservation paradigm	Perfecto I, Vandermeer J	2008	Annals of the New York Academy of Sciences	146

[a]Denotes publication included in multiple top ten lists

Table S9 Top ten citations for the search term 'resilience'

Title	Author	Year	Journal	Citations
[a]Agricultural sustainability: Concepts, principles and evidence	Pretty J	2008	Philosophical Transactions of the Royal Society B: Biological Sciences	200
Tropical Soils and Food Security: The Next 50 Years	Stocking MA	2003	Science	88
Assessing a farm's sustainability: Insights from resilience thinking	Darnhofer I, Fairweather J, Moller H	2010	International Journl of Agricultural Sustainability	46
Agroecologically efficient agricultural systems for smallholder farmers: Contributions to food sovereignty	Altieri MA, Funes-Monzote FR, Petersen P	2012	Agronomy for Sustainable Development	42
Ecosystem services in biologically diversified versus conventional farming systems: Benefits, externalities, and trade-offs	Kremen C, Miles A	2012	Ecology and Society	32
[a]The Campesino-to-Campesino agroecology movement of ANAP in Cuba: Social process methodology in the construction of sustainable peasant agriculture and food sovereignty	Rosset PM, Sosa BM, Jaime AMR, Lozano DRA	2011	Journal of Peasant Studies	31
Agroecology: A review from a global-change perspective	Tomich TP, et al	2011	Annual Review of Environment and Resources	28
Prospects from agroecology and industrial ecology for animal production in the 21st century	Dumont B, Fortun-Lamothe L, Jouven M, Thomas M, Tichit M	2013	Animal	25
Modelling loss of resilience in agroecosystems: Rangelands in Botswana	Perrings C, Stern DI	2000	Environmental and Resource Eonomics	23
Systems approaches and properties, and agroecosystem health	Okey BW	1996	Journal of Environmental Management	23

[a]Denotes publication included in multiple top ten lists

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