

Review article

Agroecology as a science, a movement and a practice. A review

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Abstract – Agroecology involves various approaches to solve actual challenges of agricultural production. Though agroecology initially dealt primarily with crop production and protection aspects, in recent decades new dimensions such as environmental, social, economic, ethical and development issues are becoming relevant. Today, the term ‘agroecology’ means either a scientific discipline, agricultural practice, or political or social movement. Here we study the different meanings of agroecology. For that we analyse the historical development of agroecology. We present examples from USA, Brazil, Germany, and France. We study and discuss the evolution of different meanings agroecology. The use of the term agroecology can be traced back to the 1930s. Until the 1960s agroecology referred only as a purely scientific discipline. Then, different branches of agroecology developed. Following environmental movements in the 1960s that went against industrial agriculture, agroecology evolved and fostered agroecological movements in the 1990s. Agroecology as an agricultural practice emerged in the 1980s, and was often intertwined with movements. Further, the scales and dimensions of agroecological investigations changed over the past 80 years from the plot and field scales to the farm and agroecosystem scales. Actually three approaches persist: (1) investigations at plot and field scales, (2) investigations at the agroecosystem and farm scales, and (3) investigations covering the whole food system. These different approaches of agroecological science can be explained by the history of nations. In France, agroecology was mainly understood as a farming practice and to certain extent as a movement, whereas the corresponding scientific discipline was agronomy. In Germany, agroecology has a long tradition as a scientific discipline. In the USA and in Brazil all three interpretations of agroecology occur, albeit with a predominance of agroecology as a science in the USA and a stronger emphasis on movement and agricultural practice in Brazil. These varied meanings of the term agroecology cause confusion among scientists and the public, and we recommend that those who publish using this term be explicit in their interpretation.

agroecosystem / Brazil / food system / France / Germany / rural development / scientific discipline / sustainable agriculture / USA

1. INTRODUCTION

The term ‘agroecology’ was first used in two scientific publications by Bensin (1928, 1930), and most recently in books by Gliessman (2007) and Warner (2007a). Between these dates, there are 80 years of history and confusion around definitions. The term agroecology has been used increasingly in scientific literature in recent years. For instance, the occurrence of the root agroecolog* or agro-ecolog* in the Web of Science increased from six in 1991 to 141 in 2007. The figures in a CAB abstracts search include two records in 1971; 102 in 1991; and 208 in 2007. This clearly indicates a great potential source of new information and perspective in agriculture and food systems. The term agroecology is currently used with quite different meanings in science, and

also as describing a movement or agricultural practices. We recognise that confusion around the world concerning the term agroecology is partly due to translations, but also to meanings among and within different cultures. Our objectives are to explore and discuss three major uses of the term agroecology: science, movement and practice. Based on the historical development of agroecology in various time periods and geographical contexts, we discuss the evolution of its different meanings with examples from Europe (France and Germany), North America (USA), and South America (Brazil). To complete this analysis of the history of agroecology as a scientific discipline, we also consider some important reports that cover similar issues but where the term agroecology is not explicitly mentioned. The intent is to clarify use of the word “agroecology” and to urge colleagues to be explicit in definition when the term is used in the future.

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Table I. Important works in the history of Agroecology (adapted from Gliessman, 2007).

Year	Author	Title
1928	Bensin	Agroecological characteristics description and classification of the local corn varieties chorotypes ¹
1928	Klages	Crop ecology and ecological crop geography in the agronomic curriculum ²
1930	Bensin	Possibilities for international cooperation in agroecological investigations ²
1930	Friederichs	Die Grundfragen und Gesetzmäßigkeiten der land- und forstwirtschaftlichen Zoologie ¹
1938	Papadakis	Compendium on crop ecology
1939	Hanson	Ecology in agriculture ²
1942	Klages	Ecological crop geography ¹
1950	Tischler	Ergebnisse und Probleme der Agrarökologie ²
1956	Azzi	Agricultural ecology ¹
1965	Tischler	Agrarökologie ¹
1967	Hénin	Les acquisitions techniques en production végétale et leurs applications ²
1973	Janzen	Tropical agroecosystems ²
1976	INTECOL	Report on an International Programme for analysis of agro-ecosystems ³
1978	Gliessman	Memorias del Seminario regional sobre la agricultura agricola tradicional ³
1979	Cox and Atkins	Agricultural ecology: an analysis of world food production systems ¹
1981	Gliessman et al.	The ecological basis for the application of traditional agricultural technology in the management of tropical agroecosystems ²
1983	Altieri	Agroecology ¹
1984	Douglass (ed.)	Agricultural sustainability in a changing world order ¹
1987	Arrignon	Agro-écologie des zones arides et sub-humides ¹
1987	Conway	The properties of agroecosystems ²
1989a	Altieri	Agroecology: A new research and development paradigm for world agriculture ²
1990	Gliessman (ed.)	Agroecology: researching the ecological basis for sustainable agriculture ¹
1991	Caporali	Ecologia per l'agricoltura ¹
1995	Altieri	Agroecology: the science of sustainable agriculture (3rd edition) ¹
1997	Gliessman	Agroecology: ecological processes in sustainable agriculture ¹
2003	Dalgaard et al.	Agroecology, scaling and interdisciplinarity ²
2003	Francis et al.	Agroecology: the ecology of food systems ²
2004	Clements and Shrestha (eds.)	New dimensions in agroecology ¹
2007	Gliessman	Agroecology: the ecology of sustainable food systems ¹
2007a	Warner	Agroecology in action: extending alternative agriculture through social networks ¹

¹ Book.² Journal article.³ Conference proceedings or report.

2. TWO MAJOR HISTORICAL PERIODS OF AGROECOLOGY

2.1. The 'old age' of agroecology: 1930s–1960s

The word “agroecology” emerged at the beginning of the 20th century. Thereafter, both its definition and scope evolved significantly. This path primarily can be related to the evolution of two disciplines from which agroecology is derived, agronomy and ecology, but also to other disciplines such as zoology and botany/plant physiology, and their applications in agricultural and environmental issues. The term agroecology or agroecological was firstly used by Bensin (1928, 1930, 1935) (Tab. I), a Russian agronomist, who suggested the term ‘agroecology’ to describe the use of ecological methods in research on commercial crop plants (Bensin, 1930 cited in Klages, 1942). Agroecology would hence be preliminarily defined as the application of ecology in agriculture – a meaning which is still used.

In the 1950s, the German ecologist/zoologist Tischler (1950, 1953, 1959, 1961) published several articles in which he used the term agroecology. He presented results of agroecological research, in particular on pest management, and discussed unsolved problems concerning soil biology, insect biocenosis interactions and plant protection in agricultural landscapes, including also non-cultivated habitats. His book was probably the first to be actually titled ‘agroecology’ (Tischler, 1965). He analysed the different components such as plants, animals, soils, and climate, and their interactions within an agroecosystem as well as the impact of human agricultural management on these components. This approach combines ecology, especially the interactions among biological components at the field or agroecosystem level, and agronomy with a focus on the integration of agricultural management.

Between the 1930s and 1960s related studies were published, without using the word agroecology in the title, that in effect applied the meanings of agroecology that predominated in this period. The German zoologist Friederichs (1930), who

also worked in the tropics, published a book on agricultural zoology and related ecological/environmental factors for plant protection. This book presented different pest management strategies, including biological control and the role of natural habitats for pest management, and evaluated the economic impact of pest damage. His approach was very similar to that of Tischler. A second important book on agroecology was published by the U.S. agronomist Klages (1942), whose article in 1928 (Klages, 1928) may be one of the first papers dealing with agroecology without explicitly using the term, and this included research on the distribution of crop plants using a physiological basis. He also analysed the ecological, technological, socioeconomic and historical factors influencing their production; his vision is quite different from that of the zoologists. Although Klages (1942) used the term agroecology only once, his contribution and that of Friederichs (1930) can be seen as the basis for later publications about agroecology. Thus the first scientists to introduce agroecology were rooted in the biological sciences, particularly zoology (Friederichs, 1930) and agronomy and crop physiology (Klages, 1928, 1942; Bensin, 1928, 1935).

At the end of the 1960s, the French agronomist Hénin (1967) defined agronomy as being ‘an applied ecology to plant production and agricultural land management’. This is not far from Bensin’s definition, without actually using the word ‘agroecology’. The Italian scientist Azzi (1956) defined ‘agricultural ecology’ as the study of the physical characteristics of environment, climate and soil, in relation to the development of agricultural plants, e.g. the quantity and quality of yield and seeds. However, he did not include entomological aspects in his analysis. The foundation of his work was already laid 30 years before (Azzi, 1928, 1942).

2.2. Expansion of agroecology: 1970s–2000s

From the 1970s agroecology continued to be defined as a scientific discipline, but also gradually emerged both as a movement and as a set of practices beginning in the 1980s (Fig. 1). Here the general trends toward movements and practical applications are described, with specifics discussed in the ‘country’ examples since they are generally case-specific. We also observe the close association today between focus on agroecology and work in sustainable agriculture, often by the same people in science and development.

Concerning agroecology as a scientific discipline, greater historical detail from the 1970s until present is given in Hecht (1995), Francis et al. (2003) and Gliessman (2007). They noted that through the 1960s and 1970s there was a gradual increase in applying ecology to agriculture, partially in response to the Green Revolution that created greater intensification and specialisation. During this period an important influence also derived from research on traditional farming systems in tropical and subtropical developing countries (e.g. Janzen, 1973). Organic farming as an alternative model was discussed in relation to agroecology, for example by Rosset and Altieri (1997) and Guthman (2000). This period was marked by an increasing interest of an ecological point of view on agriculture. The key

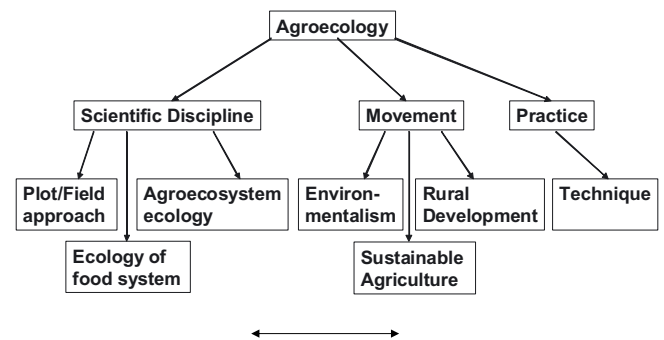


Figure 1. Diversity of current types of meanings of agroecology.

concept of agroecosystems emerged in the 1970s. It was suggested by the ecologist Odum (1969, quoted in Altieri 1995), who considered them as ‘domesticated ecosystems’, intermediate between natural and fabricated ecosystems. Since the beginning of the 1980s, agroecology has emerged as a distinct conceptual framework with holistic methods for the study of agroecosystems. Agroecology became defined as a way to protect natural resources, with guidelines to design and manage sustainable agroecosystems (Altieri, 1989a; Gliessman, 1997). Conway (1987) further developed the concept and identified four main properties of agroecosystems: productivity, stability, sustainability and equity. As its influence grew, agroecology contributed to the concept of sustainability in agriculture, mainly applied at the level of the farming system and supported in the proceedings of a conference edited by Douglass (1984), and later expanded by Gliessman (1990) and Altieri (1995). During the 1990s, agroecological research approaches emerged, several textbooks were published, and academic research and education programmes were put into motion, in particular in the USA. Recently, higher education programmes in agroecology have been developed in the USA and Europe.

Finally, agroecology as a scientific discipline went through a strong change, moving beyond the field or agroecosystem scales towards a larger focus on the whole food system, defined as a global network of food production, distribution and consumption (Gliessman, 2007). In this perspective, producers and consumers are seen as actively connected parts of the system (see also Hill, 1985). This entails a new and larger definition of agroecology as ‘the integrative study of the ecology of the entire food systems, encompassing ecological, economic and social dimensions, or more simply the ecology of food systems’ (Francis et al., 2003). However, we observe that more restricted definitions of agroecology as a discipline, focussing on the field or agroecosystem scales, are still favoured in different countries as described later.

In general, the environmental movements in the 1960s often emerged as a consequence of the unexpected impacts of industrialised agriculture after the Green Revolution. Researchers with narrow focus on short-term yields and economic returns considered environmental and social factors to be externalities. Public policies rarely considered the environmental impact of agriculture, nor the social consequences of a uni-dimensional rural development focussed on production and economics.

This environmentalism was primarily concerned with the impacts of toxic substances, in particular pesticides, on the environment. Other non-agricultural topics of these environmental movements included industrial pollution, nature conservation, and distribution of benefits. Nevertheless, in the 1960s, 1970s and 1980s the term agroecology generally was not used to explicitly describe a movement. This started in the 1990s, especially in the USA and Latin America, when the word started to be used to express a new way to consider agriculture and its relationships with society.

Almost in the same period a third word usage emerged, that of recognising a set of agricultural practices which aims at developing a more “environmental-friendly” or “sustainable” agriculture. An international example is described in LEISA (2008). One of the origins of agroecology as a practice was laid during the 1980s in Latin America. It was seen as the basis for an agricultural development framework, supported by ecologists, agronomists and ethnobotanists working especially in Mexico and Central America. Agroecology helped local farmers to improve their indigenous farming practices as an alternative to a high input, chemical-intensive agriculture promoted by international corporations (see Altieri, 1989a, 1995; Gliessman, 2007). Practices such as conservation of natural resources, adapted soil fertility management and conservation of agrobiodiversity are the practical basis for the different agroecological movements in Latin America (see country example Brazil). Another example for agroecology as a practice is described by Arrignon (1987), who illustrates technical, more adapted methods in agriculture such as water and livestock management or anti-erosion measures as a basis for rural and sustainable development in arid and sub-humid areas. Today there are many different types of movements sharing this view which do not explicitly use the term agroecology, including those of multinational chemical and seed companies that define their new-generation products and transgenic crops as essential to long-term sustainability.

3. EXAMPLES FROM DIFFERENT COUNTRIES

3.1. Case study of the USA

In the USA, a long history of agroecology as a science began with the work of the agronomist Bensin (1930, 1935), concurrent with research of crop physiologist Hanson (1939) and agronomist Klages (1942). Thus the foundation in the USA was mainly laid in agronomy. According to Hecht (1995), a second advance in agroecology in the 1960s and 1970s was shown by a gradual increase in applying ecology to agriculture. At the same time as the Green Revolution – with its non-ecological, chemical-intensive practices, maximum yield breeding strategies, and monoculture specialisation – there was a reaction that promoted a renewal of agroecology. Since the early 1970s there has been an enormous expansion of literature with an agroecological perspective. For instance, Cox and Atkins (1979) provided a broad overview and in-depth analysis concerning the dynamics of agroecosystems, including political, economic and energy-related questions.

An important influence was injected from research on traditional farming systems in developing countries, especially in Latin America (e.g. Gliessman et al., 1981; Altieri 1989a, for more examples see Hecht, 1995). Researchers recognised that traditional management of agroecosystems in these countries represented ecologically based strategies for agricultural production, often linking crop and animal production as well as natural resources. Later, the scientific focus of agroecology gained influence in U.S. west coast universities, incorporating entomology, agronomy and ethnobotany (Altieri, 1993). Agroecology had matured to look more closely at the potentials of building biological connections in agriculture.

In the first half of the 20th century, biological interactions were examined as part of the emergence of ecology as a science, but they were strongly neglected from the 1950s to the 1970s due to the large use of pesticides in crop protection. After two to three decades of decline, the evidence of negative pesticide drawbacks revived the study of ecological agriculture that was tied to advanced knowledge in biology. In this period, agroecology contributed to the emergence, definition and consolidation of the concept of sustainable agriculture (Douglass, 1984; Altieri, 1989a, 1995; Gliessman, 1990, 1997). Finally, the initial definitions for agroecology were expanded to “the ecology of food systems” (Francis et al., 2003; Gliessman, 2007).

The environmental movement in the USA appeared in the 1960s (Altieri, 1989a, 1995; Hecht, 1995). Environmentalism was primarily concerned with the impacts of toxic substances, in particular pesticides, on the environment. The publication of Rachel Carson’s book ‘Silent Spring’ was one of the sparks in the early 1960s, providing a critical appraisal of the relationships among agricultural technology, science and nature (Carson, 1964). Today, agroecology plays an important role as a movement towards extending alternative agriculture, through agroecological partnerships between farmers and extension specialists in social networks (Warner, 2007a).

Agroecological partnerships as a movement (Warner, 2007a) suggest that the term ‘agroecological practices’ was commonly used to describe techniques for improving product quality while avoiding environmental impacts (Warner, 2005, 2007a, b). Other authors identify traditional knowledge systems (e.g. Norgaard, 1984; Raza, 2007) and resource-poor small farmers (e.g. Altieri, 2002) as target groups for agroecological transitions. Warner focuses on the heart of industrial agriculture, where conventional growers employ seasonal foreign workers. He works toward realizing Rachel Carson’s ‘dream’, setting agroecology in action through socio-technical networks associating producers, extension agents and consumers-citizens who support such alternatives (Warner, 2007a).

In summary agroecology in the USA was first explored by scientists concerned with environmental pollution from agriculture who built up a scientific corpus based on analyses of traditional and conventional practices. As this expanded to larger scale agriculture, the research evolved into a scientific discipline and laid a foundation for agroecological movements in supporting sustainability, rural development, and

environmental improvement, all of which helped to promote agroecological practices.

3.2. Case study of Brazil

In contrast to the USA, the foundation of agroecology was laid in Brazil with different types of movements, based on traditional agricultural practices, and not from science. These movements emerged in the 1970s as different forms of alternative agriculture, from a critical appraisal of the effects of agricultural modernisation on farmers and subsequently towards promoting family farms, as well as food sovereignty and autonomy. In the 1970s, the agronomist Lutzenberger (1976) strived to influence environmentalists and farmers' groups, often supported by NGOs and the Catholic Church, towards an alternative agriculture. With his "Brazilian ecological manifesto: 'The end of future?'" , Lutzenberger launched a crusade against contamination by pesticides. He subsequently became involved in practising and teaching organic agriculture (Lutzenberger, 1981). This movement grew from concern about environmental deterioration, and also traditional and small farmers' social exclusion from agricultural modernisation (Norgaard, 1984). Lutzenberger later served as national secretary of the environment for Brazil.

Early in the 1980s, both the first "National meeting of alternative agriculture" (convened by the Federation of Brazilian Agronomists) and the creation of the "Advisory body and services to projects in alternative agriculture" (AS-PTA) formalized a network of organisations in 10 Brazilian states (Canuto, 1998). AS-PTA's work led to the first 'National Meeting of Agroecology' in 2001. Among its objectives, this meeting aimed at making agroecology more visible and at lobbying in the national elections. As a result, a Brazilian law in December 2003 gave formal recognition to agroecology under the umbrella of organic farming (Bellon and Abreu, 2006). In this law, participatory guarantee systems (Oliviera and Santos, 2004) and political dimension of agroecology (Byé et al., 2002) were described as important to support small farmers and foster rural communities.

Byé et al. (2002) highlight the appearance of the Ecovida network of agroecology in three states of south Brazil in 1998, as a militant process contributing to a social alternative. For Ecovida, the objectives were to break with organic agriculture third-party certification systems and formal markets, and to approach local markets through a partnership with consumers. Likewise, the Association of Organic Producers from Paraná (AOPA), created in 1995, became the Association for the Development of Agroecology in 2004. The National Articulation of Agroecology (ANA) appeared in 2002 as a space for convergence of movements, networks and organisations from civil society, bringing together groups involved in concrete experiences to promote agroecology and sustainable development in various regions in Brazil.

The Agroecological Movement of Latin-America (MAELA) declared in 1998 its "opposition to degrade nature and society". It advocated "the management and control of natural resources without depending on external

inputs (chemicals and genetically modified organisms)" and indicated "its assistance to promote, exchange and extend local experiences of civil resistance and to foster the generation of alternatives to use and maintain local varieties" (MAELA, 2000, quoted by Sevilla Guzmán, 2001).

The Brazilian technical assistance and rural extension public policy also promotes the implementation of agroecological principles through participatory approaches (MDA, 2004). This contributes to the new paradigm 'sustainable rural development', wherein agroecology is considered as one eligible approach (Sevilla Guzmán, 2001, 2002). In public extension services (EMATER) from the southern state of Rio Grande do Sul, agroecology generates a wide disciplinary matrix integrating various forms of knowledge, skills and experiences from distinct social actors, thus giving support to the new paradigm of rural development (Caporal et al., 2006). The authors are extension workers trained in Spain by the sociologist Sevilla Guzmán (2001, 2002). However, they also differentiate "agroecology" from a specific farming type, such as a production system or an agricultural technology (Caporal and Costabeber, 2000), and focus the term on alternative or sustainable agriculture for smallholders. To support their arguments and experiences, they refer to scholars such as Altieri (1989b) to optimise agroecosystems as a whole and not one single production system or activity. They also refer to Gliessman (2007) in arguing that when converting to ecologically based management, the transition levels cannot be attached to any one specific farming situation.

In general, social movements based on sovereignty and autonomy of the local populations are considered as very important and found as a common outlook in Latin America (e.g. see Caporal and Costabeber, 2000). Today in Brazil, this is stronger than ever in the southern federal states of Rio Grande do Sul, Paraná (Caporal and Morales Hernandez, 2004), and Santa Catarina where agroecology was recently institutionalised. This institutionalisation of agroecology (Brandenburg, 2002) is also criticized. For Abramovay (2007), agroecology cannot be the official doctrine at state level, since such a position would counteract scientific progress or impede the development of other production regimes, namely those that tend to serve several objectives in a given institutional context.

On the scientific side, the Brazilian Association of Agroecology (ABA) was created in 2004 (Zonin, 2007). Agroecology was officially recognised recently as a science by the Brazilian Agricultural Research Corporation (EMBRAPA, 2006). For them, agroecology is the ecology of food systems, following Francis et al. (2003), and historically emerging from alternative agriculture and small family farms. The research dimensions integrate renewed conceptual bases and methods, grounded in the work of Altieri (1995) and Gliessman (1997). Emphasis is on agroecosystems and agrobiodiversity in family farms, using systemic, interdisciplinary and participatory approaches, and also to better integrate indigenous knowledge. Agroecology is seen both as an emerging science and as a field of transdisciplinary knowledge, influenced by social, agrarian and natural sciences, especially applied ecology. However EMBRAPA also clearly stated that agroecology should be a foundation to promote sustainable agriculture and rural

development (EMBRAPA, 2006). This was strongly initiated through education programs promoted by Altieri and Sevilla Guzman.

As EMBRAPA now recognises agroecology both as a scientific perspective and as a social movement, research workers are re-connected with family farmers' situations, but also with extension workers and high level agricultural training curricula. A final example for a combined scientific and movement approach for agroecology is the Latin American Scientific Society of Agroecology (SOCLA, 2007). Its goal is to promote the development of agroecology as the scientific basis of a sustainable development strategy in Latin America which emphasises food sovereignty, conservation of natural resources and agrobiodiversity and empowers rural social movements.

In summary, agroecology in Brazil was first a movement for rural development and environmental aspects in agriculture. This stimulated a search for alternative practices, now more often called agroecological practices, which were also related to the dynamics of organic farming. In recent years, agroecology has also been considered a scientific discipline, based on an adaptation of the U.S. scientific interpretation of agroecology with an integration of social dimensions.

3.3. Case study of Germany

Germany has a long history of the scientific discipline of agroecology. From 1930 to present, most research on agroecology has been located within the different faculties of agricultural science and has provided much of the major foundation for agroecology as a science. The starting point was applied zoology with questions concerning crop protection (Friederichs, 1930), and later the ecology of agricultural landscapes (Tischler, 1950, 1953, 1959, 1961, 1965; Heydemann, 1953). Brauns (1985) further developed and broadened agroecology by analysing industrialisation of agriculture and environmental impacts such as herbicides, fertilisers, and water pollution on agroecosystems and their agro-biocoenosis. Agroecological research was extended to the Tropics and Subtropics by Koch et al. (1990). They described the need to thoroughly analyse site parameters, and biocoenosis in agroecosystem, to be able to elaborate strategies and management options for more sustainable local cropping systems.

In addition to the classical ecological factors within an agroecosystem, Schilke (1992) presented, the economic and political influences on agriculture, as well as social consequences for the rural population. Although Schilke does not provide any definition of agroecology, and although his book is not a classical scientific book but rather was written for high school students, he considers this field as the ecology of the food systems (as in Francis et al., 2003). The most recent book by Martin and Sauerborn (2006) finally combines basic ecology and applied agronomy such as farming, crop production and crop protection.

In Germany, a still more restrictive use of the term agroecology in relation to scale is commonly used, and this can be described as agroecosystems ecology or ecology of the agricultural landscapes, or even restricted to the field scale (Fig. 1).

For example, Martin and Sauerborn (2006) described agroecology as the science of the conditions for the existence of organisms in the environment, which is managed by man toward the production of certain crops. This is in agreement with the tradition of Tischler (1965), who defined agroecology as the science of life events in the agricultural parts of the landscape. The definition of agroecology provided by the Department of Crop Science (section of agroecology) at the University of Göttingen (2008), probably summarises best both the evolution and the most common current definition of agroecology in Germany: 'Agroecological analyses focus on plant and animal communities, food web interactions, and conservation biology in temperate as well as tropical agricultural landscapes and agroecosystems'. This meaning is widely used in Germany, as compared to the USA where a broader definition including food systems tends to overshadow the narrow field or landscape meaning.

Thus far, the term agroecology as related to movements is more or less nonexistent in Germany. Normally the terms 'environmental movement' or 'ecological movement' are used. These started in the 1970s in opposition against different types of environmental pollution from industry or from nuclear power stations (Brüggemeier and Engels, 2005). In the 1980s the objectives of these movements expanded to include topics such as nature conservation, death of forests in Germany due to acid rain, destruction of tropical forests, or destruction of the ozone layer. Thus far, in only very rare cases some NGOs (e.g. AGRECOL, 2008) speak of an agroecological movement; yet these NGOs are working almost exclusively in Latin America.

To summarise for Germany, agroecology is almost exclusively considered within the scientific sphere with a relatively similar interpretation today as used in the past. The focus ranges from field to landscape analyses, mainly based on ecological and biological scientific approaches.

3.4. Case study of France

In France, agroecology is not established as a specific scientific discipline. The French Institute for Agricultural Research (INRA), the largest research organization in agriculture in Europe, has not yet positioned itself nor provided a definition of agroecology, even if the word is becoming more broadly used. At present, the term is used with meaning not far from that of Altieri (1995), focussing on the analysis of agroecosystems for the design of agricultural systems. Agroecology is mentioned only once in the general conclusions of a recent French book on agronomy (Doré et al., 2006). This rare use of the word agroecology in science seems to be strongly related to two historical trends. The first is that agronomy until recently was clearly separated in education and research institutions from the scientific disciplines dealing with crop protection and breeding, and to some extent from ecology. This did not favour integration with agronomy, in particular knowledge about the biotic components of the agrarian system, which have only been integrated in recent years. The second factor is the long history of the discipline of agronomy in France (Robin et al.,

2007). Hénin (1967) has given the already mentioned definition of agronomy, and Sebillotte (1974) gave scientific ground to the discipline, agronomy in France has emphasized a systemic approach to agriculture. This led to the development of two scientific directions in agronomy: (i) an analytical direction towards the ecophysiology of plant species, and (ii) a more holistic direction considering the entire agroecosystem, including attention to farming techniques and economic and environmental performances as well. Although the cultivated field, or the plot, was considered as the primary level of attention, other larger scales such as the farm level and the association among farm units and the rural territory also became relevant to agronomy. This includes issues such as maintenance of soil fertility, quality of product at harvest, and the environmental consequences of agricultural practices such as pollution from nitrate or phosphate. Through these changes, agronomy in France has become enriched with knowledge and concepts from other disciplines, especially from the social sciences, but yet has not changed its name thus far. As a consequence, there were several similarities in regard to conceptual work between U.S. agroecology (sense of Altieri, 1995) and agronomy in France: holistic approach, integration of non-production dimensions and including the social dimension such as analysis of farmers' attitudes and practices. These are among the trends within agronomy in France, which have lasted for more than three decades. But it is clear that what is considered by others as characteristics of agroecology (sense of Francis et al., (2003) and Gliessman (2007), and particularly the ecology of the food system remains unrecognized in France.

Nevertheless the term 'agroecology' is more and more used in France. Interestingly, the English, German and Spanish web pages of Wikipedia (2008) present agroecology as a science, whereas the French web pages define agroecology as a practice, and a certain type of agriculture, which does not only respect the various ecosystems, but integrates the economic and social dimensions of human life. In fact, in many cases the term agroecology is used for describing, in a sometimes very vague manner, a way to produce more ecologically sound agricultural products in the field, or at the farm level. Sometimes agroecology is even used as a synonym for organic or ecological farming. A practice-oriented approach to agroecology has emerged over the past two decades. Although Arrignon (1987) did not give a precise definition for agroecology, he described technical, more adapted methods in agriculture as a basis for rural development in arid and sub-humid areas. This has been expanded by various institutions, with a definition of agroecology as an approach to integrate more ecological aspects into agriculture, and with special emphasis on the field scale, e.g. soil fertility conservation, water management, closed and improved nutrient cycling. Different French research institutions such as CIRAD (2007), which focuses on tropical and sub-tropical agriculture or the Non-Governmental Organisation Agronomes & Vétérinaires Sans Frontières (2007) have implemented this concept within their research and technical programmes. The latter does not give a more precise definition of agroecology than "an integrated approach of crop production, animal production and the environment". For CIRAD on the contrary, agroecology has been defined far more pre-

cisely as a technology which brings agriculture closer to the wild ecosystems, and uses the term ecological engineering (Capillon, 2006). This context is mainly based on conservation agriculture with no-tillage and mulching. Recently, the more plot-oriented approach has been expanded to include the level of field to farm linkages. It may be worth noting that this set of technologies was first applied by CIRAD outside France, for instance in Brazil, before being applied in Southeast Asia and Africa, and then re-imported to France. This technology context is now incorporated in CIRAD publications, with agroecology as a scientific discipline (sense of Altieri (1995)). In the same sense, but not within a research framework, authors like Rabhi (2007) defined agroecological techniques including recycling organic matter and using natural organisms to control pests and diseases. The "mother earth" and its organisms have to be respected in applying 'agroecological techniques', inspired by natural processes, for agricultural production (Rabhi, 2007). Humanism and solidarism are also important. Also for the editors of *Terre and Humanisme* (2007), agroecology is more a philosophy of ethics, for it also includes societal aspects.

As in Germany, the environmental movement in France started in the 1970s. Topics varied from environmental pollution from industry and from nuclear power stations. Some concerns did exist about industrialized agriculture, and different agricultural trade-unions or NGOs promoted alternative agriculture systems. But their actions were hardly realised in broader environmental movements until recent years. If one can presently speak of an agroecological movement in France, it is more in the sense to promote organic farming or more ecological friendly agriculture.

To sum up for France, agroecology was first seen as an alternative way to practice agriculture. In parallel, the evolution of the French scientific discipline agronomy gradually incorporated parts of what is called agroecology in other countries. In recent times, agroecology as a scientific discipline is on the way to becoming established with a similar interpretation as in Germany.

4. DISCUSSION

4.1. Today's scientific discipline of agroecology: a variation in definitions and scales

An interesting aspect in the different concepts and the resulting research in agroecology is the range of different spatial scales as well as the mix of disciplines that have been employed over the past 80 years. The many different definitions and descriptions shown in the publications in Table I demonstrate how agroecology has changed from focus on the plot or field scale (1930s to 1960s), to the farm, to landscape agroecosystems, and to farming and food systems scales from the 1970s into the 2000s (Fig. 2). Yet the plot and field scale approach persists up to present, with a narrow definition of applying ecological principles to farming practices by some researchers. Currently, the definitions of agroecology given by

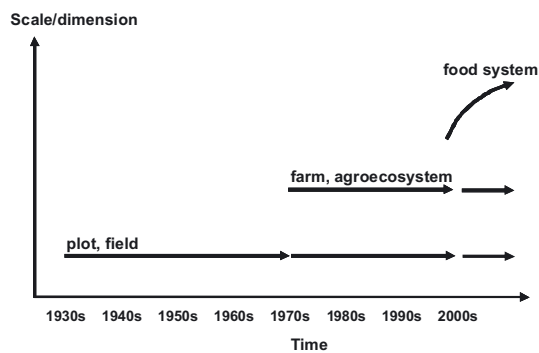


Figure 2. Temporal changes in scale and dimension in the definition of agroecology and in applied research.

Francis et al. (2003) and Gliessman (2007) go beyond the concrete spatial scale of field and farm and expand into the full dimensions of the food system. This dimension requires multi-scale and transdisciplinary approaches and methods, to include the study of food production systems, processing and marketing, economic and political decisions, and consumer habits in society. None of these can be confined nor attributed directly to a certain level of scale, but all are connected intimately with each other across scales and through time in different and complex ways.

Although agroecology as a science evolved significantly and definitions have been articulated, a large diversity still is found in approaches and definitions in different countries and regions of the world. One of the broadest definitions was provided by Francis et al. (2003) with agroecology as “the integrative study of the ecology of the entire food systems, encompassing ecological, economic and social dimensions”, or more simply “the ecology of food systems”. This approach possesses a degree of originality and inclusiveness, however clear concepts or new analysis models are not yet defined which combine the different dimensions covered by this broad umbrella for various types of analyses. A second definition, integrating the food system, is provided by Gliessman (2007) with “the science of applying ecological concepts and principles to the design and management of sustainable food systems”. This definition clearly emphasises the practical application. The definitions of Francis et al. and Gliessman are in part based on prior definitions and descriptions from Altieri (1989a, 1995). Ruiz-Rosado (2006) calls agroecology a trans-discipline because of its systems thinking and systems approach, using methods and advances from various disciplines and taking into account local knowledge where ecological, social and economic concepts and principles are applied in a reasonable manner. Similarly, Buttel (2007) describes agroecology as an interdiscipline that includes the social and human sciences as well as the ecological and agricultural sciences. Dalgaard et al. (2003) defined agroecology as “the study of the interactions between plants, animals, humans and the environment within agricultural systems” in covering “integrative studies within agronomy, ecology, sociology and economics”. From their analysis of the situation and state of the art, they concluded that agroecology could clearly be considered as a

scientific discipline. A common point in all these approaches is that if someone wants to practice this new discipline – or interdiscipline, or transdiscipline – its operational tools and concepts are still under development and difficult to identify.

Another new possible theoretical approach could follow the holon concept of Bland and Bell (2007), where every system at any level of spatial scale is composed of smaller subsystems, and in turn is a component of larger supersystems, even if this is still difficult to translate into reality. Due to the need to tackle the problems of boundary and change, which are evident for all agroecological research questions, Bland and Bell argue that agroecologists need to take into account how intentionalities seek to create holons (an intentional entity) that persist amid the ever-changing ecology of contexts, and how boundaries can be recognized based on how intentionalities draw and act upon them. This concept needs to be further developed and operationalised.

A more restricted approach in agroecology defines the system boundaries as field, farm, and landscape agroecosystems, without taking into consideration interactions with society, politics and economy. This is almost congruent with Conway (1987), although he also considers sustainability and equity as key properties of a system. A definition was presented in the case study of Germany. Among agroecosystems approaches the concepts and methods will vary depending on the definition of an agroecosystem. At the smallest level of scale, agroecological approaches are restricted to the plot or field scale. Here research almost exclusively analyses crop-insect and crop-weed interaction with a particular emphasis on natural processes, as well as impact of pesticides. For others, the farm is seen as equivalent to an agroecosystem, and still others view an agroecosystem at the scale of a local or regional landscape where agriculture is practised. According to each different choice of scale, applied research methods will vary accordingly. Based on our four country examples, it seems that these two more restricted approaches dominate in France and to a certain degree in Germany, where the mix between science and social movement in agroecology is less pronounced than in Brazil and the USA. One could conclude that in the areas where science and social movements are mixed, science is more value-laden and needs to incorporate social sciences if its goal is to be achieved.

One major constraint needs to be mentioned in evaluating the use of the term agroecology as a scientific discipline. Germany and USA used the term relatively early, thus it was found in many publications thereafter. However, many more publications exist which did not use the term agroecology in either the title or text, but which can clearly be seen as related to what we now accept as agroecology, based on current definitions. In this sense the use of the terms “agricultural ecology”, “agrarian ecology”, “ecological agriculture”, “crop ecology” or “ecological crop geography” must indeed be mentioned. In countries such as France, it is even more difficult to consider all relevant publications, as synonymous key words for agroecology took a long time to enter the literature and it is very difficult to determine when and where they were used. In general, it can be assumed that there are other valuable publications that clearly recognize agroecology as a science, but

which could not be considered here because of the difficulty in identifying them.

One unique example from nearly a century ago [first published in 1915] is the novel *Herland* by Charlotte Perkins Gilman (1992) in which a 2000-year-old society has practiced many of the key concepts in agroecology in producing food, maintaining a clean environment, and solving the challenges of population and food equity. Another is the futuristic agrarian society described by Marge Piercy (1976) in *Woman on the Edge of Time*. Both of these novels would never appear in a literature search, since they do not use the term agroecology, nonetheless they represent another way to visualise and study whole systems and their complex interactions.

Is there any concern about the confusion and lack of acceptance of agroecology as a science? All sciences evolve in their contents and definitions, and this evolution should not be considered as a problem. Nevertheless, at present there are multiple definitions, and different objects, concepts, levels of scale, and research methods. Although this can be seen as richness, our experience reveals that this rich diversity is also a source of misunderstanding. So the question persists, “Is agroecology a science?”. Dalggaard et al. (2003) provide convincing evidence, but only as applied to their specific and narrow definition of agroecology as confined to practices and farming systems. It would be erroneous to apply their conclusion to agroecology in general, without considering the great differences among the different meanings and definitions when applying the conventional scientific criteria of communalism, universality, disinterestedness, originality and doubt. As a result, one should not automatically assume that “agroecology” is a science without giving a precise meaning to the word.

4.2. Agroecology as a movement or a practice

What is an agroecological movement? So far, it is not possible to clearly answer this due to a broad variety of these movements as illustrated in the different country cases. An agroecological movement can be a farmers’ group working for food security, sovereignty, and autonomy. Or it could be a more political movement of the local population for rural development (Brazil). Or it can be a farmers’ group movement for extending alternative agriculture through social partnerships to better respond to ecological and environmental challenges within relatively specialised agricultural production systems as in the USA. These movements are clearly action-oriented, and in general happen in response to higher common goals such as sustainable development and sustainable agriculture.

Much of the early project work that today we could call “an agroecological movement” did not actually use the term at all, and often they were within the framework of larger environmental activities. This causes certain unbalance in the country studies. In the USA, for example, Hecht (1995) mentions that the environmental movements of the 1970s enhanced agroecology as a science. In contrast, such relations between movement and science were never established in Germany, thus knowledge about similar movements is confined to publications using the term agroecology.

In general, agroecological practices are seen as new, modified, or adapted practices or techniques that contribute to a more environmentally friendly, ecological, organic or alternative agriculture. They are used to improve traditional or indigenous agriculture in developing countries. The different practices are appropriate to their related objectives, definitions, and to certification in the case of organic farming. For traditional agriculture, practices are mainly for soil fertility and organic matter management or resource conservation, or techniques for low external input systems. Biological pest management or soil fertility enhancing techniques are major objectives for environmentally friendly, organic or alternative agriculture. Conversely, agroecology challenges the interpretation of organic farming as mere input substitution rather than redesign of the system (Rosset and Altieri, 1997), and also may soften the division made by ecoagriculture between productive and natural areas (Altieri, 2004).

As with science, the lack of precise definition of agroecological movements or practices may be seen as a weakness. Indeed, everyone supports the goal of a more sustainable agriculture, and thus everyone could claim that his or her own movement could be called agroecology. The same type of difficulty is recognised in describing agroecological practices. At present, an agroecological practice is one that is not ecologically harmful, although this may not be scientifically grounded. In some cases, the environmental problems which practices are supposed to solve are not clarified, adding more to the confusion.

4.3. Combined use of the three definitions

In many countries there is a combined use of the term “agroecology” as a movement, as a science and as a practice, and in most situations they are strongly intertwined. In Germany, agroecology has a long tradition as a scientific discipline, and the term is not associated with a movement or with practices. In the USA and in Brazil, agroecology is used to describe all three activities, with a predominance toward science in the USA and a stronger movement and/or practice emphasis in Brazil. In France, agroecology was mainly known until recently as a practice. In the countries where the agroecological movements are well established, the idea of practises is strongly connected, or even incorporated, into these movements. Here, they merge for the objective to develop and assist a transition into sustainable agroecosystems (e.g. Wojtkowski, 2002; Gliessman, 2007) and also with other models such as traditional, alternative or organic farming. There is large overlap in use of these several terms.

In this sense agroecology encourages farmers and extensionists to participate in the design of new systems, and also contribute to social movements. This is particularly the case for Brazil, and to certain extent for the USA and France. In these situations, there is often a link between a political vision (the movement), a technological application (the practices) to achieve the goals, and a way to produce the knowledge (the science). A key-point here for the scientists is to assess how these tight connections may influence the science of

agroecology, where there will be application to meet a political vision using a set of technological practices. This association raises serious questions for some who have seen science more as an objective activity that is somewhat disconnected from practice. For example, when the science agroecology is defined as the scientific basis of a sustainable development strategy which emphasises food sovereignty, conservation of natural resources and agrobiodiversity and empowers rural social movements, the science itself may appear as an advocacy activity that will be impacted by diverse goals and applications of results. Instead of considering agroecology as a general matrix including the wider range of disciplines (Caporal et al., 2006), collaborations between agricultural, natural and social scientists should help to clarify such embedded interpretations of agroecology. One must ask, of course, whether this connection between the science and the practice is any different from our accepted linkages between research and recommendation, for example studies of fertilizer rates, types of pesticide that are effective, or scheduling of irrigation. Especially in the USA, where land grant university faculty are often involved in both research and extension, there is often a close connection between these activities.

4.4. Agroecology, a history of oppositions?

In analysing the historical evolution of agroecology, either as a science, movement or practice, it becomes evident that different topics, discussions or debates in certain periods seem to have provoked major changes or reactions within agroecology. The common ground in the U.S. evolutions in agroecology was to find a scientific basis for new alternative agricultural systems. But why did this concern evolve to a new scientific discipline in the USA, but not in France, at least not so soon, where the concern was also present? Maybe because the holistic definition of agronomy, and the included concepts in France could welcome part of the changes needed to target this goal, which was not the case in the USA. Therefore a rupture was sooner necessary in the USA, leading to the creation of a new scientific discipline. For the case of Brazil, a clear rupture can also be mentioned. The expansion of different farmers' agricultural movements in the 1980s and 1990s was finally translated into agroecological movements whose common interests have been canalized under the term agroecology. In addition, to better distinguish their practical approach from industrialised agricultural practices, it seems that the use of the term 'agroecological practices' fulfilled this best. In speaking of agroecological practices since the 1990s, a possibility was found to distinguish them clearly from other conventional practices. Thus, a sort of new identity was created for these practices, which considered for instance more ecological and environmental aspects. In contrast to the USA and to Brazil, the different types of movements have not been the starting point for agroecological movements in France and Germany, or did not provoke a clear reaction into agroecological research. This might be explained by the fact that the agricultural problems in Europe interested or concerned only a limited part of the population. In Brazil on the contrary, a larger part of

people are involved in agriculture, and the questions of rural poverty and disparities in agricultural land tenure still are important topics. In the case of Germany the lack of social movement around agriculture can also be explained considering that ecology in general, and in particular ecology related questions to agriculture, have been already well established in research, and thus evolved gradually instead of creating new research fields as for example in the USA. As usual in a scientific community, it can also be noticed that ideas attached to agroecology have crossed national borders. Therefore, many authors attached to a specific institution also gained and communicated knowledge from other countries, for instance through exchanges between Europe and the Americas.

4.5. Future questions and challenges of the scientific discipline of agroecology

Many open questions remain for the scientific discipline of agroecology, especially for those who embrace the definition as the ecology of food systems. What new concepts, new models, and new methods need to be developed or adapted in order to grapple with this expanded definition of agroecology? Do we need new competencies for researchers and educators dealing with this more holistic and systemic approach (Lieblein et al., 2007b)? These authors raise the question of how higher education and learning activities will need to be modified to deal with systems, uncertainty, and complexity? Lieblein et al. (2000, 2007a, b) have proposed experiential learning strategies, but still the essential contents of agroecology courses have to be clarified and their applications defined for different cultures and perhaps for different ecoregions. Most authors also demand that the scientific discipline of agroecology should provide results for practical application in the design and management of sustainable agroecosystems. It is important to work out the crucial interfaces between the scientific discipline of agroecology and the needs of different stakeholders. It is important that particular participatory or on-farm approaches be employed, which also take into account the social, cultural and ethical dimensions. Although these questions cannot be answered quickly nor easily, and although a certain misunderstanding in using the term agroecology will persist, it will be intriguing to observe the evolution of the terms and their applications in this rapidly changing learning and development landscape. Moreover, it will be interesting to see how the word will escape the fatal challenge of being marginalized as too vague, confusing, and ineffective by scientists, farmers, environmentalists and consumers who want to express their ecological concerns in relation to agriculture and to move these concerns into effective action.

5. CONCLUSIONS

Today there is certain confusion in use of the term "agroecology". We have described the three main definitions of the term: as a scientific discipline, as a movement, and as a practice. Application of the term depends strongly on the historical evolution and epistemology, that provide the foundation,

scope and validity of use of the term, in different countries. The most important influencing factors are (i) the existence of strong social or environmental movements, (ii) the existence of different scientific traditions and their evolutions, and (iii) the search for frameworks and concepts to describe new types of practices or movements.

From the historical analysis it became clear that the scientific discipline of agroecology and its scales, dimensions and definitions distinctly evolved from beginnings in the 1930s. We could illustrate that scales, and with them the definitions, expanded spatially over the next 80 years from the plot or field scale to the farm or agroecosystem scale, and finally leaving a concrete spatial scale or place and entering the entire realm of the food system. Today, all these three different scale approaches still exist within agroecology. The preference to any one of these approaches seems to depend in many cases on the historical evolution in different countries, at least in those we could analyse. In spite of the existence of different approaches and definitions, the new views and dimensions brought into agroecology as a scientific discipline will help facilitate the efforts to respond to the actual challenges of agricultural production, because of increasingly applied systems thinking and interdisciplinary research approaches.

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