Agroecology and the Food System

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2 authors:

A. Wezel
ISARA-Lyon

Christophe David
ISARA-Lyon

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A. Wezel and C. David

Abstract On a global scale agriculture and food will face key challenges of properly feeding a population of nine billion individuals in 2050, while preserving the ecosystems from which other services are also expected, such as bioenergy production, biodiversity use and conservation, carbon storage and climate regulation. To develop future sustainable agricultural production and food systems, agronomic, ecological, economic and social challenges have to simultaneously be taken into account. The framework of agroecology applied on the food system could be a useful concept to support this development. Although the scale and dimension of scientific research in agroecology has been enlarged in the last years towards the food system approach, it is still difficult to outline clear concepts, new models and new methods that specify it. In using two contrasted research case studies, we evaluate benefits and challenges using the framework of agroecology applied on the food system.

The first case study illustrates research questions around water quality and management of shallow lakes with fish production, biodiversity of the lakes, agricultural land use on the surrounding land, and local fish products and its marketing strategies. It shows that research was initiated by an ecologist working at the lake scale, but implementing quite quickly a systems approach in integrating the disciplines ecology, agronomy, geography, socio-economy and sociology with a food systems approach. The second case study illustrates research questions around organic wheat production and food chain. It shows the evolution of a research program where research objectives and methodology have been slowly turned from technical questions on nitrogen management of organic wheat, supported by agronomist, applied at field scale, to overall agroecological questions around organic grain producers,

A. Wezel (✉) • C. David
Department of Agroecosystems, Environment and Production,
ISARA Lyon (associated member of the University of Lyon), 23 rue Jean Baldassini,
69364 Lyon cedex 07, France
e-mail: wezel@isara.fr

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raised by economists, sociologists, agronomists and food technologists, focussing on the wheat-flour food chain, applied at farm and food system scales.

This chapter underlines the importance of the articulation between disciplines such as agronomy, ecology and social science. In using the food system approach, the indispensable interdisciplinary research is carried out automatically by integrating other disciplines such as sociology, socio-economy and geography supporting the disciplines of agronomy and ecology. This chapter also shows that in combining already existing research methods from different disciplines, and applying them to different scales, a concept for agroecological analyses of the food system already exists. In conclusion, we propose necessary prerequisites for agroecological research with the food system approach: ex-ante impact anticipation of expected results when starting research, multi-scale and interdisciplinary research as well as scale related impact assessment of proposed recommendations. In considering these prerequisites, quality of agricultural research will substantially improve in the future, and thus contributing in search for more sustainable food systems.

Keywords Agroecosystem • Food chain • Interdisciplinary research • Multi-scale research • Organic agriculture • Wheat • Pond • Shallow lake • Sustainable agriculture

1 Introduction

World agriculture and food provision will face key challenges of properly feeding a population of nine billion individuals in 2050 where contrasted regional food availability will support important migration. Therefore, there is a crucial need to preserve the environment and natural resources of agricultural land from which other services are also expected: bioenergy production, biodiversity use and conservation, carbon storage and climate regulation. Research on the world's agricultural production and food, to support the objective of sustainable development, has become the subject of many studies and debates (FAO 2003; Agrimonde 2009). The framework of agroecology applied on the food system may significantly support this sustainable development by considering simultaneously agronomic, ecological, economic and social dimension at different scales.

Although agroecology as a scientific discipline exists already since many decades, the food systems approach in agroecology has been developed only recently (Wezel and Soldat 2009; Wezel and Jauneau 2011). Still it is difficult to outline clear concepts, new models and new methods that specify this approach. Besides agroecology as a scientific discipline, other interpretations such as agroecology as a practice or as a movement are present (Wezel et al. 2009).

The scale and dimension of scientific research in agroecology has been enlarged over the past 80 years from (1) the plot, field or animal scale to (2) the farm or agroecosystem scale and finally in the last years to (3) the dimension of the food system (Wezel and Soldat 2009). On the plot/field/animal scale, the aim of agroecological research is to develop new farming practices such as more efficient use of natural resources, improved nutrient cycling, and enhancement of diversity and the health of soils, crops and livestock. For instance, in crop production research focuses on techniques to limit off-farm fertilisers, e.g. mixed crops, intercropping systems to better use crop diversity and N fixation from legumes or to improve pest management by using natural processes, e.g. allopathy or natural enemies for plant protection. In animal production, research investigates for example natural alternatives like plant extracts to antibiotics or adaptation of animal densities and pasture rotation to improve fodder quality and availability. At this scale, research does not really consider interactions and implications of these techniques on the agroecosystem or the environment at a larger scale.

The second major approach is the agroecosystem approach. Here, ongoing research dominates the agroecosystem scale, including exchange with, and impact on the surrounding environment. Agroecological analyses focuses on plant and animal communities, food web interactions, and conservation biology in agricultural landscapes and agroecosystems (Department of Crop Science, Section of Agroecology, at the University of Göttingen 2008). Within the agroecosystem approach the definitions and concepts might vary depending on the delimitation of an agroecosystem. Sometimes, the farm is seen as equivalent to an agroecosystem where the relations between farmers' practices and natural resources are analysed (Conway 1987). For others an agroecosystem is larger, that is, a local or regional landscape where relations between different types of agriculture and the natural resources of the landscape is investigated.

The most recent and broadest approach is the food systems approach. This approach was firstly defined by Francis et al. (2003) 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'. Gliessman (2007) stated that the politics/policy dimension should also be included in this definition, as the different political decisions and policies are an important issue to be considered. This author defined agroecology as 'the science of applying ecological concepts and principles to the design and management of sustainable food systems'. These two definitions are based on former definitions of Altieri (1989, 1995, 2002).

During the beginning of the 2000s, several authors demand that agriculture has to be analysed in a holistic manner. For example Robertson et al. (2004) demand that agricultural research needs long-term, system-level research at multiple scales, and that natural and social science must be better integrated. Gliessman (2007) stated that 'to recognise the influence of social, economic, cultural, and political factors on agriculture, we must eventually shift our focus from sustainability of agroecosystems to the sustainability of our food systems'. Nevertheless, it is still difficult to outline clear concepts, new theoretical models, and new methods that specify and translate these demands, and in particular the expanded definition of agroecology of the food system, into concrete cases. In fact, very few papers are given in the literature where agroecology concepts and theory are applied on the food system, e.g. Francis and Rickerl (2004).

This leads to the objectives of this paper. Two examples of actual research topics will be presented and analysed in how they are placed within or in relation with the food systems approach of agroecology. A particular question will be what distinguishes them from more disciplinary research approaches such as agronomy or ecology, which research concepts are used and how the different research scales are taken into consideration.

In the following, we will present the two case studies, the agroecosystems where they have been carried out, the research objectives and the main research questions, the methods used to analyse them, and the interaction between the different research components and disciplines. A special emphasis will be laid on the historical evolution of the research objectives, which disciplines initiated the projects, and which disciplines joined in thereafter. In a subsequent section their place within the agroecology approach with the food system will be illustrated and discussed.

2 Shallow Lake Agroecosystem: Biodiversity, Agriculture and Fish Production

The research objectives of this case study were, first, to evaluate if shallow lake management practices and agricultural practices in the surroundings favour high biodiversity which can then be used for the promotion of local fish products, and, secondly, if the agricultural and aquaculture practices at the same time can maintain a sufficient level of fish production and preserve un acceptable water quality.

The Dombes region in south-eastern France, the study area, was formed by glacial activity during the quaternary period (Avocat 1975). It is a plateau of about 1,000 km^2 with long, fan-shaped morainic mounds, so-called drumlins. The average altitude is about 280 m. The plateau is flanked by three fluvial valleys about 50–100 m below the plateau. During the late Würm glaciation, substantial amounts of loess were mainly deposited in the depressions between the drumlins (Williams 2006). Post-glacial rain leached much of the loess creating decalcified clayey soils in the depressions which induce water stagnation when soils are wet (Avocat 1975). In the morainic areas, more sandy soils dominate. Annual precipitation varies between 800 and 1,200 mm (Blanchet 1993; Bernard and Lebreton 2007). The history of the Dombes and its shallow lake system started in the thirteenth century (Guichenon 1650 cited in Sceau 1980). The shallow lakes were created in smaller depressions for the production of fish, and to drain surrounding loamy-clayey soils to be able to crop cereals. The fish production activity expanded largely during the medieval period because of the need to find fish at a time in which food prescriptions were very strict. Today, the Dombes region is characterised by about 1,100 shallow lakes with about 12,000 ha, located in an agricultural area with pastures, cropped fields and forests (Bernard and Lebreton 2007). The size of the shallow lakes varies considerably from less than 1 ha up to one which is larger than 100 ha. Average depth of the shallow lakes is about 1 m. The fish farming practiced in the shallow lakes is oriented toward raising mainly carp, but also tench, roach and pike

(Bernard and Lebreton 2007). It is based on an extensive system that alternates fish farming and grain farming on the same unit of land. Shallow lakes are emptied every year for fish harvesting, and then refilled. After 3–4 years, the shallow lakes are left to dry up to be cultivated mainly with oats, maize or sorghum for 1 year; few are not cultivated (Wezel et al. submitted). The water that fills the shallow lakes during the wet phase comes either from a shallow lake situated at a higher elevation or from a system of ditches which lead into the shallow lake and which collect rainwater from the catchment.

The research presently carried out in the Dombes region touches different scales and different disciplines. At the scale of a shallow lake, which is considered here as the plot/field scale mentioned above, different physical-chemical water and sediment parameter are analysed for a selection of shallow lakes to evaluate the trophic status and its changes during a year (ecology). This type of research was started already a few years earlier, before other components were added to have a more holistic approach. For the latter, species richness and diversity of phytoplankton, marcophytes, macro-invertebrates, dragonflies and amphibians are additionally investigated (ecology). Also data on annual fish harvest are collected from managers of the shallow lakes (socio-economy). Land use and biotopes within a 100 m radius around the shallow lakes (field scale) and within the catchment of shallow lakes (agroecosystems scale) are analysed by aerial photograph interpretation and ground surveys (geography, landscape ecology). In addition, farmers are interviewed about their agricultural practices such as fertilisation, nutrient management, pesticide use and water drainage on the fields adjacent to the shallow lakes and in the catchment (field scale; agronomy). Owners or managers of the shallow lakes are questions concerning different fish production and lake management practices (lake/field scale; socio-economy). Finally, an analysis is carried out to investigate the network of stakeholder for processing, selling and marketing of the fish production, and about the creation of a label of geographical denomination of origin for the fish products (food system scale; sociology, socio-economy).

The different analyses carried out are used to evaluate either singular results of the different parameters analysed, but also their complex interactions. Water quality and sediment parameter are analysed to evaluate the trophic status of the shallow lakes itself, but also how these parameters are influenced by land use around and lake management practices. The richness and diversity of the different species groups are evaluated in relation to the trophic status of the shallow lakes, but also in relation to lake management as well as for agricultural practices and biotopes present in the vicinity of lakes. The evaluation of the fish production is the most complex as fish production is evaluated in relation to trophic status of shallow lakes, which is additionally influenced by lake management practices and agricultural land use around the lakes. In addition, the impact of several species groups such as phytoplankton, marcophytes, and macro-invertebrates, are evaluate in relation to fish production because of being a source of feed for fish or being important for nutrient turn-over in the water. Finally, it is evaluated if the existence of a certain biodiversity (the species groups and the biotopes) can be valorised for the marketing of the fish production, or more specifically for a product label, or even as being a quality

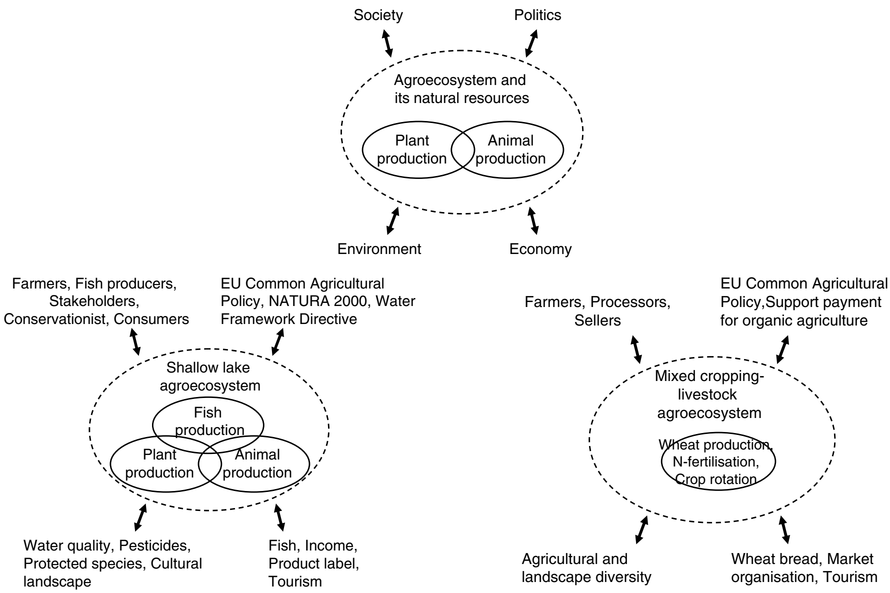

Fig. 1 The general food systems approach of agroecology is illustrated above (From Wezel and Soldat 2009) where agricultural production within an agroecosystem and the interactions and influences from and to the environment, economy, society and politics are taken into account. Below left, the case study of the shallow lake agroecosystem, and below right, the case study of organic cereal farming, are illustrated with the respective key elements

indicator for the Dombes shallow lakes agroecosystem and its different types of management and practices.

2.1 Shallow Lake Agroecosystem and the Agroecology of the Food System Approach

In this section we will show how this first case study can illustrate the theoretical concept of Francis et al. (2003) for the food system approach in agroecology. The agroecosystem of this case study consists of shallow lakes within a matrix of agricultural land forests and (semi-)natural ecosystems (Fig. 1, *below left*). Three types of production exist and interact in different ways: fish production in shallow lakes, cropping of cereals, sun flowers and rape on fields as well as cattle and some sheep production on pastures. These three types of production have different impacts on the environment. The use of fertilisers and pesticides for plant production influences to different degrees the water quality of shallow lakes (Vallod et al. 2008, Wezel et al. submitted), and thus also fish production, but also different natural species in and around the shallow lakes such as dragon flies, phytoplankton or macrophytes. The impact strongly depends on where the different types of land use are located in the agroecosystem, and how they are connected by ditches or drainage systems with the shallow lakes. In addition, it is necessary to know how farmers manage their fields and pastures as well as their borders or the hedgerows in the agroecosystem. This together with the knowledge about how fish producers mange their shallow lakes is necessary to evaluate the impact on ecosystems such as reed, hedgerows, thickets and grassland as well as selected species groups in the shallow lakes vicinity. The management of the farmers and fish producers is influenced to different degrees by regional, national and European regulations such as the EU Common Agricultural Policy, the European Water Framework Directive and NATURA 2000, thus these regulations have to be taken into account if modification of practices are intended. In addition, the role of farmers and fish producer among other stakeholders in the Dombes agroecosystem such as local politicians, mayors, conservationist and different agricultural and fish associations and institutions has to be analysed to anticipate reaction within the social structure of the Dombes region to proposed changes or innovations. Finally, it is essential to identify the different stakeholders of the fish food chain: from producers, collectors, processors, sellers to the consumer. This analysis enable to evaluate how fish could be marketed in increasing or assuring income by using different types of labels such as Geographical Denomination of Origin, or a new local label indicating that with the traditional local fish production the cultural landscape and/or biodiversity is preserved.

This case study illustrates the food system approach with research questions around water quality and management of shallow lakes with fish production, biodiversity of the lakes, agricultural land use on the surrounding agricultural land, and local fish products and its marketing strategies. It shows that research was initiated by ecologist, but implementing quite quickly a systems approach in integrating the disciplines ecology, agronomy, geography, socio-economy and social science with an agroecosystems and food systems approach.

3 Organic Wheat: From Production to Wheat-Flour Food Chain

The research objectives of this case study were, first, to evaluate how nitrogen management of organic wheat can be improved and how the farming system has to be adapted to this, and, secondly, to analyse the organisation of organic grain producers and the wheat-flour food chain.

The study area is located in south-eastern France where two closely located subareas, the Diois and the Plain of Valence, were selected. The Diois is a hilly area located along the Drome River, at the southern feet of the vast karst plateau of the Vercors with an average altitude of 1,100 m. The altitude of the Diois ranges between 420 and 520 m with a mean annual temperature of 10.2°C (David et al. 2005a). In this area, clayey and stony soils dominate, except along the Drome River where cereals are produced on alluvial soils. Annual precipitation varies between 885 and 1,100 mm. The traditional farming system is characterized by a mixed production of livestock with sheep and goats, arable crops and perennial crops such as aromatic plants, walnuts or grapes. Climatic conditions with cold winter and dry summer limit strongly wheat performance.

The Plain of Valence is located at the confluence of the fertile Rhone, Drome and Isere River valleys where loamy and sandy soils dominate. The altitude ranges between 150 and 250 m with a mean annual temperature of 11.4°C (David et al. 2005a). Annual precipitation varies between 850 and 950 mm. The traditional farming system mainly produces grains, sometimes in combination with other productions such as poultry or field vegetables.

In the two districts, where the study areas are located, the development of the organic sector (production and processors) in the last year has been one of the fastest growing in France with 8–10% of the usable agricultural area under organic agriculture (Agence Bio 2008). In particular in the Diois area, an active organic sector around wine, grains and aromatic plants has developed since the beginning of the 1990s.

As the Dombes example, this research project has been carried out at different scales and by integrating different disciplines. The on-farm research program on organic wheat started in 1993, and up to 1998 the objective was to improve the technical and economical performance of organic grain systems with a special emphasis on organic wheat being the most important crop (Von Fragstein et al. 1997). This first phase had been set up on 17 farms, first, to take into account a wider range of growing conditions than is available on on-station experiments, secondly, to benefit from farmers' expert knowledge when research on organic grains systems was still very limited, and, finally, to consider the entire farm system and its socio-economic parameters (Lockeretz and Stopes 1999). Nitrogen and weed management were experimented on more than 40 organic fields from 1993 to 1998 by testing various techniques and equipment (field scale, agronomy) defined by experts to improve yield performance. Different factors limiting organic crop production such as weed and pest infestation, soil compaction or climatic conditions like water stress and hot temperatures could be determined (field scale; agronomy) (David et al. 2005a; Casagrande et al. 2009). From 1998 to 2004, management of N fertilisation had also been studied under controlled on-station conditions, to produce references for N nutrition of organic and low-input wheat from organic N sources (David et al. 2004). This research also allowed developing a decision support system to manage N fertilisation of organic wheat (David et al. 2005b; David and Jeuffroy 2009) to improve grain yield and grain protein content. In addition, it gave an early indication of whether this decision support system is likely to be adopted by farmers (agronomy, sociology). During the second phase of the program, research went beyond the restricted field scale analyses in integrating more farm management aspects. A multivariate analysis of quantitative and qualitative data such as grain yield, protein content, crop management and farming system management from 97 organic farms located in the two districts demonstrated the incidence of the farming systems, e.g. the presence or absence of livestock on the farm, the incidence of crop management, e.g. cultivar, preceding crop, N fertilisation and weed control, but also the incidence of soil and climatic conditions such as water deficit and temperature on grain yield and protein content (field and agroecosystem scale; agronomy). Furthermore, interviews with farmers which were started in the first phase, enlarged in the second phase and which became up to present a key element of the research program, enabled to study more completely the farm management (plot, farm and food system scale; agronomy, economy and sociology). It could be concluded that diversification of farm production and activities, off-farm employment and professional and social networking contributed significantly to farm viability (David et al. 2010). In parallel, the analysis of the wheat-flour food chain allowed to determine the interactions between producers, collectors, processors and consumers (David and Joud 2008). Also, a structured organic food chain supported by cooperatives and bakers improved economic viability of farms.

The present research project now tries to integrate even more many different scientific disciplines such as agronomy, food technology, economy, and sociology, and to work simultaneously at different scales of the field, the farm and the food system to consider a more holistic approach. Thus, the present research objectives are to improve nitrogen supply by undersowing of leguminous species or use of organic fertiliser and soil management for wheat production, but also flour processing to improve baking quality, nutritional value and to avoid mycotoxin contamination. Further research questions are how local and regional processing, marketing, distribution and selling enterprises in the region can be establish or better implemented in the region in considering the increasing requirements from processors on quality and safety of organic wheat as well as the demand from the regional and national organic food market to decrease the variation of offer and quality as well as to limit instability of prices? And last but nor least, how can the organic farmers be better integrated in this food chain network, also considering the different support payment systems on national and European level for organic agriculture?

3.1 Organic Wheat and the Agroecology of the Food System Approach

As for the first case study, we also will illustrate the theoretical concept of Francis et al. (2003) for the food system approach in agroecology with the organic farming case study. The agroecosystems characteristics of the two subareas of this case study strongly influences the farming systems but also the food system (Fig. 1, *below right*). The Diois agroecosystem consists of limited areas with fertile soil in the Drome Valley, where cereals are produced in a long term and diversified crop rotation of 8–11 years, surrounded by large areas with low soil fertility occupied by vineyards, lavender fields, permanent pastures and (semi-)natural ecosystems. The agricultural productivity is limited in this area. In contrast, the high agricultural diversity together with the Drome River and the adjacent mountains make it to a beautiful landscape and give a strong value for tourism for which farmers produce local food, vine and lavender as well as offering accommodation. Conversion to organic production allowed maintaining economic value to low-input agricultural productions like vine, grains and aromatic plants. Moreover, the organic development, promoted by local authorities, supports the "natural" value of this area. The marketing of organic products such as grain, wine and aromatic plants, promoted by cooperatives is associated with identity and origin, supported by traditional varieties and specific products, for instance by the Clairette de Die, a famous sweet sparkling wine produced exclusively in this area.

As the agroecosystem of the Plain of Valence consists of a large fertile plain, yield performance of dominating grain production is much higher, compared to the Diois. Organic grain systems differ only slightly from conventional systems. Cropping systems are based on a balanced proportion of spring crops, mostly irrigated, such as maize and soybean associated in the crop rotation of 4–6 years with winter cereals such as wheat, barley or triticale. The organic grains are collected by conventional cooperatives where a limited organic sector has been developed to answer farmers' requirements. Tourism is very limited in the Plain of Valence area, thus direct selling, provision with local food products or accommodation at farm are rare.

As shown above, the agroecosystems characteristics of the two subareas do not only influence the farming systems but implicate also differences for the food system (Fig. 1, below right). For instance, in the Diois, the wheat-flour-bread chain is essentially based on small niche market for traditional organic bakers or organic retailers looking for specific flavour obtained with ancient varieties, but also providing identity as originating from the area. On the contrary, the wheat-flour food chain in the Plain of Valence is essentially based on standardised quality requirement, e.g. protein content over the conventional threshold of 11.5 g per 100 g and no mycotoxin, applied from mass distribution or enterprises (David and Joud 2008). Nevertheless, on-going research clearly needs to demonstrate the incidence of crop management, in particular N fertilisation, interaction with environmental conditions soil and climate via wheat flour quality to local, regional or national marketing and selling networks. In this relation from the field to the food chain scale, farmers' management goals, their economic situation and their receptivity for innovations, e.g. reduced tillage or undersowing of leguminous species, as well as regional, national and European agricultural policy framework have to be taken into consideration.

This case study illustrates research questions around organic wheat production and food chain in a study area in south-eastern France. It also shows the evolution of a research program since 1993 where research objectives and methodology have been slowly turned from technical questions on nitrogen management of organic wheat, supported by agronomist, applied at field scale, to overall agroecological questions around organic grain producers, raised by economists, sociologists, agronomists and food technologists, focussing on the wheat-flour food chain, applied at farm and food system scales.

4 Agroecology and the Food System Concept

At present, a crucial and highly debated question in relation to agroecology of the food system is if new research concepts are needed or if already adequate concepts and approaches exist which can be used immediately. In our opinion existing concepts and approaches should be valorised, and new one should be developed. We will start with existing concepts, than coming to new potential ones.

In general, the concepts of holism with a systemic approach including different scales and interdisciplinarity exist already, so they can already be the basis for research and analyses for agroecology of the food system. The two case studies presented above show how analyses and evaluations from the field/plot, the farm/agroecosystem, and the food system scale can be used to orient research towards a system approach. Nonetheless, it is essential to emphasize on the up-scaling methods to relate research questions from the field/plot to the food system. The two research examples clearly demonstrate the value of interdisciplinary research combining agronomy, ecology, social sciences, socio-economy, but also food technology. If we really intend to establish sustainable agricultural systems, it is essential to focus research questions around a food product, or more generally around an agricultural commodity, and to analyse the different scales with an interdisciplinary perspective. Two types of research approaches seem possible, a bottom-up and a top-down approach. The bottom-up approach would be for example to analyse the incidence of innovative fertilisation management for crop performance and for farm management, but also to anticipate what type of impact this would have on the agroecosystem and the food quality (Le Bail and Meynard 2003). Which analyses or what type of investigations have to be considered to evaluate their potential impacts? The top-down approach could also be applied. For example if a local or regional food label want to be created for better marketing, specific requirement along the food chain, but also by specific values or 'capitals' from the agroecosystem have to be taken into account. Consequently, the analyses have to be related to the social systems and networks as well as to the agroecosystem itself to know for instance if it is a particular cultural landscape which preserves certain species or certain ecosystems, and thus if this information could be used for the promotion of the product.

In general, different theoretical models have been developed to conceptualise the complex relationships of how agroecosystems exist in the intersection between nature and society (Gliessman 2007). The models presented focus on sustainable agroecosystem and influences from ecological, socio-economic, and technological factors (Hernandéz Xolocotzi 1977, cited in Gliessman 2007), the relation of agroecosystems to certain resources, called 'capitals' such as human, social, natural, and financial capital (Flora 2001), and the interactions among social and ecological components of sustainable agroecosystems (Gliessman 2007). Although some of the factors, capitals, or components are related in different ways to the food system, the food systems approach is not explicitly integrated within the models.

Other possible theoretical approach could be the holon approach of Bland and Bell (2007). Due to the need to tackle the problems of boundaries, e.g. scales, system limits, or actors, and change, e.g. time or evolutions and adaptations, that are evident for all agroecological research questions, they argue that agroecologists need to take into account how intentionalities, e.g. research objectives, seek to create holons, an intentional entity, that persist amid the ever changing contexts, and how boundaries can be recognized based on how intentionalities draw and act upon them.

Nevertheless, this interesting concept remains difficult to be translated into reality. The multi-scale approach is not necessarily used, as a holon can be restricted to the field or the agroecosystem scale, although holons are always part of something larger (Koester 1967, cited in Bland and Bell 2007). This ecology of contexts seems to be very similar to what we see as the agroecology of the food system approach, where the environmental, social, economic and political contexts always have to be taken into account. Bell et al. (2008) state that productivity of variability should be a key principle in agroecology as contextual variability across space and time presents farmers with productive opportunities. This clearly underlines that agroecological research should be carried out simultaneously at different scales if it is intended to be systemic or holistic, also because a multi-dimensional approach touches automatically variability across time, in our examples for instance considerations on long-term impacts such as N fertilisation and N supply of organic wheat performance and flour quality, or investment decisions in perspective of EU agricultural policy regulations to support organic product with guarantee of safety and quality. Although not directly discussing agroecology, Pretty (2008) arguments also clearly that it is necessary to simultaneously consider and analyse natural, social, human, physical and financial capital dimensions to shape concepts for agricultural sustainability, the core topic of agroecology. A practical example on how such different dimension can be evaluated simultaneously is the filter approach of Haigis et al. (1999). In using agroecological, technical, institutional, sociological and economic filters, different technology options for small-scale farmers were interdisciplinary evaluated for their acceptance or rejection. Although this method was not explicitly developed to evaluate a food system, it is one example of an already existing tool which could be further adapted to the food systems approach.

In any case, irrespective to theoretical models or tools that wanted to be used to analyse the food system, it has to be struggled with a high complexity of research questions. If the holistic and system approach really wants to be achieved, we have to think this from the conception of agroecological research in connecting different disciplines from the beginning, different research scales as well as implications of food systems stakeholders. It is also essential to previously fix the boundaries, with the limits of our food system we intend to analyse, and the key disciplines regarding the research questions. For the food system approach of agroecology this would demand that in particular the disciplines agronomy, ecology, geography, socio-economy, sociology and anthropology have to be integrated (Fig. 2). Depending on the research questions, other disciplines such as food technology, as mentioned by organic wheat case study, should be also considered.

5 Future Agroecological Research

Although the basis and the historical origin of agroecology are founded in the two disciplines agronomy and ecology, the present scientific discipline agroecology and its approach to the food system seems to be the most promising research framework

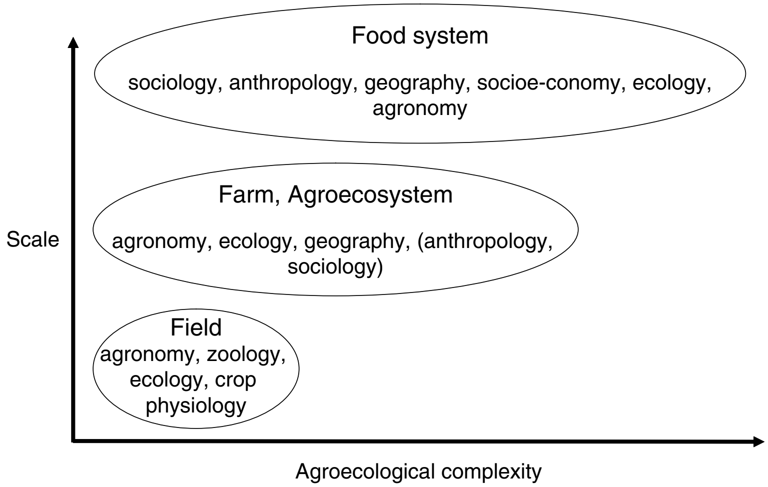

Fig. 2 Agroecological complexity for research with different scale approaches of agroecology. The increasing scales used for the farm/agroecosystem and the food system approach of agroecology demand considering an increasing number of disciplines to deal with increasing complexity of research questions. Agronomy and ecology are the basic disciplines for all scale approaches. The disciplines in brackets are so far only integrated in certain cases at the farm/agroecosystem scale

to respond to actual questions on sustainable agricultural productions systems where ecological, economic and social sustainability aspects are strongly linked. Francis and Rickerl (2004) as well as Robertson et al. (2004) provided already a future vision for the ecology of the food system and a vision for environmental research in US agriculture. Based on this and our own experience, we think that four prerequisites are necessary for carrying out research with the agroecology of the food system approach:

(a) Agroecological research has to be carried out simultaneously at different scales.
(b) Agroecological research has to integrate different scientific disciplines as well as stakeholders from the different food system networks.
(c) Potential environmental, social and economical impacts from the expected research results have to be anticipated during development of a research project and its hypothesis.
(d) Recommendations from agroecological research have to be impact assessment-driven for the different scales.

Without the holistic/systems approach of agroecology and the food system, the different research topics of our case studies would have been treated in a restricted, more disciplinary way, in looking only at parts of the systems – which can be of course also valuable in many cases. But in using the food system approach, the indispensable interdisciplinary research is carried out automatically as shown by the two examples. The two examples also show that in combining already existing research methods from different disciplines, and applying them to different scales, a concept for agroecological analyses of the food system already exists. Nevertheless, our examples also show that they remain to a certain degree incomplete. For example among key social factors in food systems sustainability such as equitability, sustainable diet patterns, control of population growth, and self-sufficiency and bioregionalism, as proposed by Gliessman (2007), only bioregionalism was considered in the Dombes example. We could add more factors to that list which we think as important to be included in food systems analyses such as energy consumption, transport, or food quality, but probably we should also accept that is unrealistic to demand now that every potential parameter or factor has to be included in the analyses. In practice it is evident that it is not that easy to carry out such type of necessary research as it will be seldom financed in its totality, but rather as research projects which analyse only parts of it. In addition, interdisciplinarity is a keyword commonly used everywhere today in the scientific research community, but being really implemented in only rarer cases.

It is also indispensable to integrate the stakeholders from the different food system networks. With this a broader vision of the problems and a better identification of potential solutions are achievable. Consequently, a more client-oriented research will be implemented. Nevertheless, it should not be forgotten that integrating researchers and food system stakeholders in a common process is often a tricky thing as it demands a lot of efforts to find a common language and understanding. It also often slows down the starting phase of the research projects as so many things have to be taken into account, e.g. identification of stakeholders, common workshops or meetings, agreeing on terms and definitions.

Prerequisite three demands that already during the construction of an agroecological research project and the establishment of the research hypothesis, potential environmental, economic or social impacts or problems of the expected results have to be anticipated. For example, the intention to test different levels of liquid manure application to the shallow lakes to increase fish production, as in case study 1, should be first evaluated in respect to an increased nutrient status in the water which might have a negative impact on nearby rivers when shallow lakes are emptied once a year. If negative impacts seem to be possible, then the research approach should be adapted and modified. Anticipating potential impacts at the field scale is of course probably easier than at the agroecosystem scale.

Our fourth prerequisite for agroecology of the food system is that recommendations from agroecological research have to be impact assessment-driven for the different scales. That means that results obtained at a certain scale should be evaluated in respect to their potential impacts at other scales. For example, before recommending a certain amount of N fertilisation for organic wheat, as it proved to increase significantly yields or baking quality, it has to be evaluated if these N inputs might create N leaching and drinking water contamination in the watershed in certain periods of the year, or if the necessary organic fertilisers, or the grains of undersown leguminous species, are not available on the regional market or are too expensive or to energy demanding during production.

We are aware that the four prerequisites for agroecology of the food system approach are not that easy to be completely fulfilled for all research programs. Nevertheless, we are sure that if the food system approach is already taken into account during the design of a research project, and be it only during reflections at an initial stage of the project, it will substantially improve the quality of agricultural research in the future, and thus contributing in search for more sustainable food systems.

In this paper we focused on agroecology and the food system from a scientific research perspective, but as mentioned before, a strong link of agroecology and the food systems has also been established in recent years with a development and movement perspective (e.g. Cruces 1996; Caporal and Costabeber 2000; Altieri 2002; Sevilla Guzmán 2002; Altieri and Nicholls 2008; Brandenburg 2008). The main topics in these and other papers are rural development, built on local social and cultural values, which provides food sovereignty and food security for small farmers in developing countries. Based on local and traditional knowledge, low-input alternative agricultural systems are favoured.

6 Conclusion

From the experience of the two research programs we can state that without the holistic/systems approach of agroecology and the food system, the different research topics would have been treated in a restricted, more disciplinary way, and only at lower scales. In using the food system approach, the indispensable interdisciplinary research is carried out automatically by integrating other disciplines such as sociology, socio-economy and geography to the two basic disciplines agronomy and ecology. These two case studies also show that in combining already existing research methods from different disciplines, and applying them to different scales, a concept for agroecological analyses of the food system already exists. Nevertheless, our case studies also show that they remain to a certain degree incomplete. Other important factors such as such as energy consumption or food quality could have been included, but probably we should also accept that is unrealistic to demand now that every potential parameter or factor has to be included in a food system analysis.

We finally conclude that four prerequisites are necessary for the agroecology of the food system approach: ex-ante impact anticipation of expected results when starting research, multi-scale and interdisciplinary research as well as scale related impact assessment of proposed recommendations. We assume that in considering these four prerequisites, quality of agricultural research will substantially improve in the in the future, and thus contributing in search for more sustainable food systems.

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