Published January 25, 2017

FORUM

# Agroecologist Education for Sustainable Development of Farming and Food Systems

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## ABSTRACT

Twelve educational strategies for future agroecologists are based on experiences in Nordic universities, with priorities informed by six propositions about future resource challenges. The principal objective is student learning for future challenges and contributions to sustainable development of farming and food systems, including practice in acquiring capacities needed for responsible future action. The heart of the program is learning to apply ecological principles in design of farming and food systems, using multi-criteria evaluation for prioritizing sustainability challenges, and measuring ex-ante success of transition. Working closely with farming and food system stakeholders in design and implementation of learning environment is essential, plus recognizing contributions of farmers and food system professionals as vital to education for design of future systems. Holistic approaches integrate multiple disciplines, and combine technologies developed through science with those discovered in the field. Students' prior experiences also contribute to activities in the learning landscape, and important skills are developed for autonomous and lifelong learning. Practices from organic farming and other alternative farming strategies provide useful examples, and local food systems represent one viable option that can potentially reduce food distance and food waste, and thus contribute to food security and food sovereignty. Capacities to deal with difficult challenges are developed by each student in agroecology and related courses, including observation, participation, reflection, dialogue, and visioning. These capacities are applied while completing a thesis project using natural science and social science methods that affirm their skills and prepare students well for responsible action in a complex and uncertain future.

### Core Ideas

- Ecological principles are applied in design of future farming systems.
- Close working relationships with farmers and other stakeholders are essential to education.
- Educational programs will develop autonomous and social learners.
- Local food systems provide an alternative to growing globalization of food.
- Graduate study in agroecology prepares students for responsible action in the future.

Published in Agron. J. 109:23–32 (2017)
doi:10.2134/agronj2016.05.0267
Received 6 May 2016
Accepted 15 Sept. 2016



We are faced with daunting challenges in enabling people to meet their food needs in a growth-driven global economy which increases the inequity of benefits and continues to leave many behind (IAASTD, 2009; UNCTAD, 2013; IMF, 2015). These economic realities accompany the "inconvenient truth" of environmental degradation, due to unsustainable use of non-renewable resources and externalizing costs, undermining our future agricultural production base (Foley, 2011; Foley et al., 2011; Steffen et al., 2015; Frison, 2016). Global climate changes increase uncertainty of future rainfall and harvests. Most education and research efforts on current systems are based on assumptions that increasing crop yields and livestock production efficiency will solve world hunger, and that we will have minimal changes in resource availability. Yet these systems are highly dependent on fossil fuels, universal access to inputs, and assumptions that a free market will manage resources appropriately. In the light of challenges to these assumptions, we need to re-think our priorities and pursue concerted and collective efforts to address broad issues in a major transformation of research and education.

Our objectives are (i) to provide a thought-provoking set of six propositions about the future that can guide the planning of relevant and practical education as well as agricultural and food systems research to inform that education, and following these proposed challenges, (ii) to articulate 12 useful pedagogical strategies with examples derived from our educational experience in designing learning landscapes in agroecology, defined as the ecology of food systems (Francis et al., 2003). This definition integrates the pragmatic categories described by Wezel et al. (2009) that recognize agroecology as science, practices, and movement. We conclude with recommendations on where and how we think agroecology should be infused into a future educational curriculum.

## SIX PROPOSITIONS ABOUT THE FUTURE OF AGRICULTURE AND FOOD

In contrast to prevailing assumptions that suggest our future will be essentially a continuation and fine-tuning of present systems, a mentality that currently informs much of our research and education, we believe in the creativity of people to seek new

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**Abbreviations:** SLU, Swedish University of Agricultural Science.

directions to improve society and quality of life as well as equity in resource use. It is our opinion that we can shape the future, and should not necessarily be encumbered by present conventional wisdom and inertia that inhibit creative thinking about a more desirable future situation for our species and the rest of the biosphere. Our propositions encompass challenges to such dominant contemporary paradigms as the inevitability of globalization, the confidence in new, sophisticated, and expensive technologies to solve any challenges we create, and the myth of "sustainable growth"– which many would consider an oxymoron given present human population and projected increases plus an extravagant exploitation of non-renewable resources. Thus we begin with a series of informed propositions for the future.

## Recognize and Accommodate to Natural Resource Limits and Global Climate Change

Based on all the evidence on resource depletion, especially non-renewable fossil fuels, limited fresh water supplies, scarce P resources, and arable land degradation (e.g., Brown, 2015), future systems must be designed to thrive under conditions of limited water, be sustained primarily by renewable local resources, and perform well in less stable and unpredictable climates. Although the concept of "local" is often nebulous, here local is defined to include resources such as precipitation that falls on the farm or water from nearby empoundments, N that can be captured by leguminous crops and cycled within the farming system, and human energy and creativity. The concept does not exclude trade with nearby areas, nor ignore the importance of economies of scale and specialization within society, but does recognize the costs of transporting scarce inputs and importance of people becoming secure in their food supply. Adapting to climate change, especially increasing unpredictability, requires design of biodiverse agricultural systems that are uniquely adapted to each ecological niche and display resilience and adaptability (Altieri et al., 2015). Social changes in attitudes toward food and who benefits from agriculture also need to be explored as part of food security (Frison, 2016).

## Embrace and Adapt to Human Population in Balance with Available Resources

Lasting solutions to hunger are only possible with thoughtful attention to global human population and changes in our current extravagant exploitation of land and other limited natural resources. Although we currently produce enough food to provide adequate calories and protein for the present world population, geographical distribution of production, poverty, and lack of access, use of grains for fuel and other purposes, and lack of political will all contribute to continuing hunger in much of the world (IAASTD, 2009; Foley et al., 2011; IMF, 2015). A large paradox in the food system today is that more people are overweight than are undernourished, a tragedy in distribution that creates large challenges in seeking improved nutrition, better health care, and equitable solutions (Prentice, 2006). One of the key elements in building solutions is to recognize the scarcity of resources and need for balance in their use (IAASTD, 2009). In the words of the late Nobel laureate Norman Borlaug, "There can be no permanent progress in the battle against hunger until the agencies that fight for increased food production and those that fight for population control unite in a common effort" (www.nobelprize.org/nobel_prizes/pease/laureates/1970/borlaug-lecture.html).

## Develop Systems that Rely on Appropriate Technologies and Local Resources

Total confidence in newer and more resource-intensive technologies to solve every problem and reliance on a global food system may be comfortable but misleading and dangerous. We recognize the contributions of the Green Revolution in basic grain production, but also the short-term futility of technologies that deplete renewable resources and create negative emergent properties such as increased inequality of access to food and greater differences between the rich and the poor (Evenson and Gollin, 2003). Based on an increasing international body of evidence (e.g., IAASTD, 2009; FAO, 2012, 2014), it is clear that appropriate technologies and local systems are essential. Some of our most productive agricultural systems are those with multiple crops each year, mixed plantings that promote "overyielding" compared to sole crops, and reliance on local resources including human experience (Francis, 1986; Foley et al., 2011). Although industrial-scale sole crops currently dominate the landscape in the North, they are highly dependent on scarce fossil fuels and a dwindling base of arable land. Altieri et al. (2015) have described well the potentials of small farm systems in tropical regions, confirming that these are primarily reliant on local resources including human labor.

## Replace "Monoculture Mentality" with Diverse and Creative Thinking

One challenge in agriculture and food systems is overcoming a mentality and acceptance of monoculture and uniformity that we have learned from experience in vast non-diverse fields of maize (*Zea mays* L.) or soybean [*Glycine max* (L.) Merr.]. Agro-chemicals and fertilizers have become the main strategy for controlling pests and managing soil nutrients. Beyond agriculture we have become accustomed to uniform plantings of one species of street trees, a single lawn grass cultivar, or one imported species of honeybee. Each is proving to be increasingly less biologically sustainable as we see spread of maize borer (*Ostrinia nubilalis*), soybean cyst nematode (*Heterodera glycines*), dutch elm disease (caused by *Ophiostoma ulmi*), take-all disease in lawns (*Gaeumannomyces graminis*), and colony collapse in bee hives (due to *Varroa* and *Acarapsis* mites plus other causes). Not unique to agriculture, the monoculture mentality extends to cookie cutter houses in subdivisions and exact replicas of fast-food cheeseburgers wherever we want to find them while traveling. Marketing strategies based on expected uniformity may produce short-term profits through economies of scale, but they create a biological and economic system that is less sustainable, exciting, and resilient than one built on biological diversity and multiple economic options. We must avoid the limited creativity applied in growing single crops with menu-driven practices, go beyond the parts to embrace and understand the whole, bring in environmental and social science methods, and pay attention to ethical dimensions of the food system. This theme has recently been developed in the IPES-Food report (Frison, 2016).

## Overcome Institutional Stagnation in Education and Research Planning

We need incentives for teams, collaborative research and teaching, and transdisciplinary strategies that focus on holistic, integrated, and broad systems learning including environmental and social concerns, with long-term focus beyond singular attention to crop yields and short-term systems profits (Galbraith, 1999). Research driven by available grant opportunities has replaced the academic freedom of programs with adequate base funding from state and federal sources, and the present priorities are too often informed by the immediate need for products that are patentable and profitable in the marketplace. There appear to be fewer opportunities for transformative thinking that is outside the box of current short-term profits from research and continued exploitation of scarce natural resources (Benner and Sandström, 2000).

### Evolve from Short-term "Anthropocentric" Focus to "Ecosystems" Thinking

We need performance criteria and rewards beyond traditional metrics, innovations in analysis that encourage us to consider whole systems evaluation and accountability to all stakeholders in society, current and future, plus other species and the environment. It would be well for the global science and education community, as well as the rest of society, to take seriously the conclusions of the United Nations report *Our Common Future* (WCED, 1987), that we should make decisions about resource use and preserving the environment that allow future generations to inherit the same options that we have enjoyed in our current generation. Switching from an "egocentric" to an "ecocentric" economy is essential (Scharmer and Kaufer, 2013).

These broad and futuristic assumptions or propositions may be challenged as somewhat unsubstantiated, unrealistic, or naive given the power of the present political and economic system that rewards growth based on increasing use of non-renewable resources, idolizes material wealth, and measures "progress" by quarterly gains and a single and short-term economic bottom line. Yet as described by Thomas Kuhn (1962) in *The Structure of Scientific Revolutions,* we often have to make decisions based on incomplete evidence, trust in experience, and recognize that change happens around the boundaries of accepted science and current society, and not in the mainstream. There is an increasing number of companies that subscribe to broader goals, such as the triple bottom line that considers social, environmental, and financial measures of success (Slaper and Hall, 2011). These authors are among many who have developed lists of criteria and measurement tools to quantify what could appear to be an elusive concept much more difficult to grasp than a short-term indicator about financial success as reported in the stock market. Conceptual foundations for this type of analysis were provided by Daly et al. (1989) in their seminal article, *For the Common Good: Redirecting the Economy towards Community, the Environment, and a Sustainable Future.* It has been suggested that we recognize the challenges, and have many tools available, but lack the economic, social, and political will to pursue changes that will increasingly be viewed as inevitable.

To recognize and address these major challenges, we find that philosophy and experience from academia, as well as experiences from farming and food systems practitioners, should become integral to our conceptualizing and design of learning programs in agroecology (Altieri, 1995; Francis et al., 2003; Gliessman, 2015). It is essential to respect the experience of farmers and other business people, and create opportunities to learn from them, while using science to expand available options, for example to help us better understand the mechanisms that explain how and why some crops and systems are successful. As a product of this dialogue, we are learning that it is not enough to learn about current practices and mechanisms in agriculture and appreciate what needs to be done. It is essential to move beyond understanding and move toward responsible action, and as educators develop learning environments and activities where students can learn how needed changes can be accomplished. This realization leads us to apply holistic approaches gained through agroecology and systems studies to design future educational landscapes. Educational approaches include those used to help students explore and understand sustainability challenges; the approaches and methods used to deal with specific challenges; and those learning strategies that help integrate knowledge and experience into future potential scenarios developed in dialogue with clients. Learning strategies presented here address in aggregate the overall challenges and function within the propositions described in the previous section.

## AGROECOLOGY INFORMS EDUCATIONAL STRATEGIES

We share here our experiences in transforming the learning environment in Agroecology M. Sc. programs, and describe some of the most important changes we believe will shape education in the future. Ideas for learning priorities deal with production, resource, economic, environmental, and social challenges we face in food systems, as well as the methods that have proven successful in design of active, participatory learning landscapes over the past two decades.

We define and explore each strategy, provide an example, and then describe how together they have informed design of courses in agroecology, which move beyond farming and production to embrace "the ecology of food systems" (Francis et al., 2003). We also recognize that agroecology could be described as a science, a set of practices, and a social movement, depending on the country as well as the agencies and people involved (Wezel et al., 2009). Education in action includes classes and activities, plus topics that our students pursue for their M. Sc. thesis research using an agroecological systems framework, and employing methods that embrace both biological and social sciences. In building this learning process, we provide opportunities and encourage students to embrace the following guidelines and strategies.

### Use Ecological Principles to Inform Design of Farming and Food Systems

Recent United Nations reports on future agricultural systems (UNCTAD, 2013; FAO, 2014, 2015; Frison, 2016) emphasize agroecology and use of ecological principles to design multifunctional food production strategies with emphasis on uniqueness of place, reliance on local resources, and involvement of people in each location who are essential in our research and education programs. This was confirmed by the IAASTD (2009) report from the United Nations as well as a policy paper from the Ecumenical Advocacy Alliance (Ecumenical Advocacy Alliance, 2013), a group representing various faith groups concerned about equitable options in development and food sovereignty. A recent review article summarized the types of components that characterize agroecological practices and components (Francis and Porter, 2011). These holistic principles are featured in our courses in agroecology, including attention to production, resources, economics, environment, and social impacts in the whole food system. Students working on community food systems in Norway explore all of these aspects as they interview multiple players in each location, and look for common ground in defining group priorities and potential strategies for the future. Prototype educational programs are operating in the Nordic Region, and have spawned similar initiatives in Ethiopia, Uganda, and India.

### Adapt Multi-Criteria Sustainability Assessment of Food Systems

Assessing potentials for sustainable development is essential, and often new and creative tools are needed beyond the standard measures of productivity and short-term economics. Several tools including themes and indicators for sustainable development are used by students, for example, Sustainability Assessment of Food and Agricultural Systems (SAFA) (FAO, 2012) and Sustainability Monitoring and Assessment RouTine (SMART) (FiBL, 2014). These multi-dimensional methods may be used by any groups active in food systems for self-assessment, or employed to promote dialogue between farmers, advisors, students, and scientists, among others. Agroecology student teams also develop a rich picture of what they observe in the local food system, and conduct a strengths, weaknesses, opportunities, threats (SWOT) analysis that helps to inform strategies for making positive change in the future. Some student groups employ the SAFA (2014) to quantify and put weights on factors using sustainability software now available in Version 3.0 (http://www.fao.org/3/a-i3957e.pdf). The main aim is to identify the areas where impacts can be made to further sustainable development, as well as to identify gaps in our current knowledge and experience base. This new information and especially the approach are essential for students in agroecology.

### Work with Stakeholders to Develop Shared Goals for Sustainable Development

Since sustainable development is a value-based strategy it is important to agree about key principles and goals and seek accord on these in diverse actor groups. Various sets of principles exist, for example, those of strong sustainability as defined by Daly and Farley (2011) or principles for organic farming International Federation of Organic Agriculture Movements (IFOAM) (IFOAM, 2014). Principles are not strict rules such as certification, but provide a guiding framework for prioritizing among different solutions to enhance sustainable development of farming and food systems. Without a framework of shared principles, action for sustainable development may quickly become complex with too many dilemmas that may be difficult to solve in the short term. Student teams in the field work with multiple clients in each community food system, learning about their individual and agency priorities, and seeking common ground on which to build future innovative and sustainable approaches to improving food and nutrition.

### Recognize Farmer Experience as One Valid Contributor to Farm System Design

Phenomenology includes starting on the farm and learning from farmers as the entry into research and education, then using this information to inform the search for relevant theories and ways to study mechanisms of key processes and interactions among systems components (Østergaard et al., 2010). Here we build on science from our well-known disciplines of genetics, agronomy, horticulture, plant protection, agricultural economics, and engineering. We add value to basic and applied research by integrating science with experience and seeking solutions that are practical and developed in close collaboration with stakeholders. This means elevating the value of indigenous knowledge and experience, and using this to open new doors for research into details and mechanisms. We observe how experience and practice inform theory, and in turn theory can inform practice, establishing a continuous knowledge loop (Fig. 1). Agroecology students observing and working on farms dedicate quality time to interviewing farmers to better understand how they make decisions and evaluate the results. Rather than approaching the farm as an expert advisor team, our students are guided to see this as a valuable learning experience on a par with what is gained in the classroom and on the web.

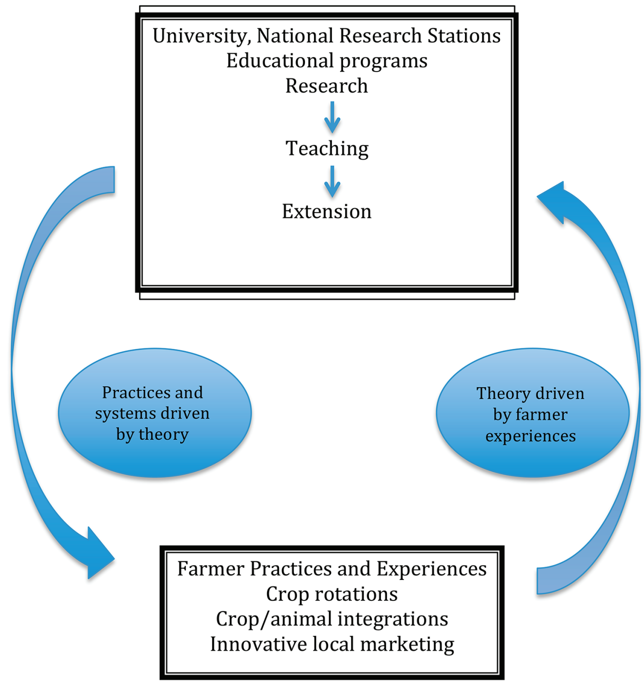


Fig. 1. Principles and theory driven by practices and experience, and practices driven by principles and theory in an active feedback cycle and knowledge loop.

### Create Holistic Understanding for Systems Evaluation and Future Scenario Design

Many advances in agricultural production are based on solid science in basic disciplines, with results contributing to greater genetic potential, more efficient use of fertilizers and water, and plant protection through Integrated Pest Management. Today we are near the genetic yield plateau in major crop species, with most production gains now coming by narrowing the gap between genetic potential and current farmer yields, primarily achieved using best management practices (Grassini et al., 2013). Focusing on whole food systems, new crops, and crop/animal combinations can provide windows on new opportunities for local food production and markets. Identifying current challenges is the first step to solving them, and to help mitigate present food shortages in many regions. For example, food waste is a huge issue, with conservative estimates of 30 to 40%

loss from production fields to the plate (Foley, 2011). Highest losses in developing countries are found in the field at harvest and in substandard storage facilities; in industrialized countries these losses occur in long supply chains, in marketing, and in wastes from consumers. Similarly, healthy human diets with less or more balanced consumption of meat need to be promoted worldwide. These are only two key issues that are undervalued in present university research agendas, where focus is primarily on the increase in yields per hectare or reduction in costs of production, and on systems with sustainable intensification, which has multiple definitions but often requires expensive technologies.

Holistic study of food systems reveals a number of important dimensions that are unseen when each system is viewed from any single discipline point of view, such as loss of biodiversity, degradation of ecosystem services, loss of prime farmland, decline of rural communities, obesity and under-nutrition, and reductions in food security and food sovereignty. Such problems are often externalized, and not paid by today's consumers. Students soon learn that these challenges are unique to each farm and community, although there are useful steps that can guide in inquiry into the study of any system at any level of scale. Agroecological methods help us uncover, explore, quantify, and understand constraints to production and profit, as well as equity of distribution and other broad food system issues, and thus inform a future agenda for research, education, and development.

## Combine Methods from Science with Practical Experience

There is often a much larger gap between knowledge and action than between ignorance and knowledge (Lieblein et al., 2012). Too often we have considered scientific research methods and results as incommensurable with ideas and experiences from farmers and food systems innovators in the field and community. In learning landscapes designed for education in agroecology, we attempt to resolve differences in methodology, design, and interpretation to embrace multiple sources of experience and knowledge. We particularly work to recognize key roles that students, farmers, and food systems professionals all play in bringing together multiple sources of information and ways of interpretation that can enrich and inform the academic quest to find mechanisms, theories, and practical applications in developing more sustainable farming and food systems. One initial step in building the class learning community is to share our prior expertise and experiences– students and instructors alike– in order to better understand the strengths we will have each semester as a team and how we can depend on and trust each other as we pursue a better understanding of specific farms or community food systems. We envision agroecology as a bridge between academia and stakeholders outside the university, helping to create and catalyze a "dialogue space" where ideas are generated and tested, and scenarios developed that can be useful in improving food systems toward increased efficiency, equitability, and sustainable development (IAASTD, 2009; Lieblein and Francis, 2013; Francis et al., 2016).

## Integrate Discipline-Derived Components into Whole Systems Scenarios

Plant breeding for increased genetic potential in rice (*Oryza sativa* L.) and wheat (*Triticum aestivum* L.) was the central component of advanced technical packages for food production in the Green Revolution (Conway, 1997). Along with expansion of cultivation into new arable lands, introduction of new varieties, addition of chemical fertilizers and pesticides, and enhanced yields with irrigation, this suite of technologies combined to double and triple major crop yields per hectare in the period of the 1960s to 1980s. Today in retrospect we recognize a wide range of emergent negative consequences that must be considered in our long-term evaluation of this revolution that did bring many people an improved food supply, but with emergent properties of high environmental and social costs (Pingali, 2012; Gupta et al., 2003). Experiences from the Green Revolution expose the clear need to integrate our research on production of crops and animals with study of environmental impacts such as water pollution, and assessment of anticipated social consequences such as consolidation of farms, displacement of limited resource farmers, increased farmer debt due to high input costs, and inequitable distribution of benefits that reduce food sovereignty for many. We encourage students in the field to avoid jumping to immediate conclusions, as this rush to judgment can easily obscure many of the subtleties that can be uncovered with an open mind and patience to let the discovery process unfold. With an integrated systems focus provided by agroecology these challenges can be revealed and even converted into opportunities for more equitable farming strategies for the future.

## Use Organic Farming as a Working Model for Sustainable Agricultural Systems

Our experience in the field confirms that organic farmers have followed principles and certification rules and applied individual creativity to establish highly biodiverse systems that incorporate nutrient cycling, planting designs to manage pests, and added value to production through unique marketing options. This makes organic farms, biodynamic farms, or other variations and their farmers valuable resource places and people for learning about integrated systems, complex biological interactions, and design of production strategies based to a high degree on eco-functional intensification and ecosystem services (Niggli et al., 2008; Bellon and Penvern, 2014; Baret et al., 2015). Although sometimes less productive in the short term than systems that depend on fossil-fuel intensive inputs, organic systems have received relatively little focused research compared to conventional fossil-fuel-dependent systems.

Within the EU research programs, the funding for biotechnology was increased from 20 to 70% of the agricultural research budget from 1998 to 2013, whereas funding for organic research never exceeded 12% (Baret et al., 2015). In fact the most successful organic farmers match or exceed conventional farm yields, and usually do this with lower economic cost and less impact on the environment (Ponisio et al., 2015; Reganold and Wachter, 2016). In fact, some practices developed for organic farmers such as cover crops and complementary rotations have been adopted by conventional farmers as well. Agroecology integrates successful methods discovered through research and farmer experience in many systems, and much of this research comes from basic laboratory studies and conventional field plots. As instructors we often use organic or biodynamic systems as examples of integrated management, but must avoid pushing these as the optimum models for students to pursue in designing their recommendations for a farm or food system. We provide ideas, options, and opportunities, and urge students to pursue their own routes toward discovering what appears most appropriate in designing scenarios for their clients.

## Maximize Use of Contemporary Resources in Local Food Systems

To design truly sustainable and location-specific agricultural production systems for the long term, it is useful to move toward practices and crop sequences that produce adequate yields using sunlight and rainfall/snowfall that arrives in that place in the current year (Altieri, 2004). Some nutrients and moisture are stored from previous seasons or years, thus in the long term the goal is to have a net positive balance that helps build soil and plant productivity and resilience in the face of scarce fertilizers, pest attacks, or periodic droughts. To import chemical nutrients and to access water at high cost in fossil fuels both create a dependency on the larger system and on non-renewable resources that can only be sustainable in the short term. Farmers planning for the long term also avoid export of forages and all the nutrients they contain from the farm, preferring to sell higher value products such as meat or milk, which makes it easier to establish a balance of extraction with what comes in from local and natural sources. Crop residues and non-marketable products represent valuable resources that should be cycled back as nutrients into the farm production process. Conversion to dependence on resources internal to the farm can reduce input costs, while often increasing creative involvement of human management and labor, and these may be seen as economic trade-offs or employment generation; both must be considered in the quest for sustainable development and system resilience.

A comparison of the current global food chain or system and an efficient local food web is summarized in Fig. 2 and 3, showing the heavy reliance of a food chain on imported or purchased inputs (Fig 2) and a food cycle or food web that depends primarily on local and contemporary resources (Fig 3). A food chain is simplistic, linear, and easy to understand, and represents an industrial model that builds on economies of scale and comparative advantage for growing crops best suited to particular climates and soils. Yet similar to the age-old saying, "a chain is as strong as its weakest link", this food system is characterized by its lack of redundancy, dependence on a linear process that may be easily disrupted, focus on imported resources, and fragility in the face of climatic, energy, and political uncertainty. The local food web model addresses all these challenges. In working with student teams, we encourage them to compare multiple alternatives and if appropriate to compare their scenarios against the food chain and food web models. Agroecology raises many appropriate questions and proposes methods for students to assess the differences, as well as design sustainable food systems for the future.

## Emphasize Social Learning, Autonomous Activity, and Lifelong Education

While agroecology courses include substantial elements of resource-efficient, alternative, and sustainable farming practices and design, we also emphasize building skills, capacities and attitudes that promote social learning, autonomous capabilities for seeking learning opportunities, and motivation toward a lifetime of continuing education. Key capacities include observational skills, meaningful participation, effective dialogue and communication, reflection, and visioning a desirable future (Lieblein et al., 2015; Francis et al., 2016). Learning to learn builds a capacity that is never obsolete. This is among the capacities we

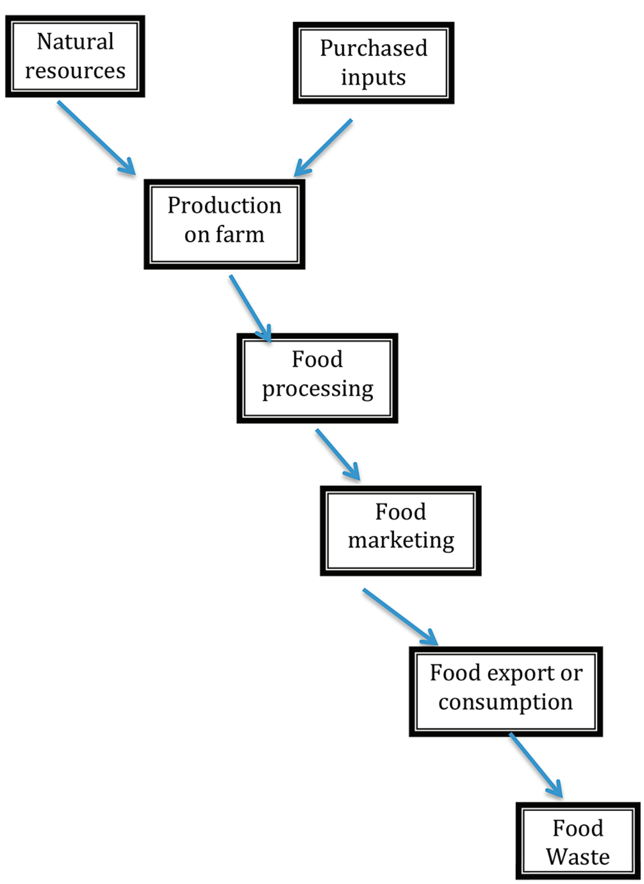


Fig. 2. Global food chain, a linear and industrial process.

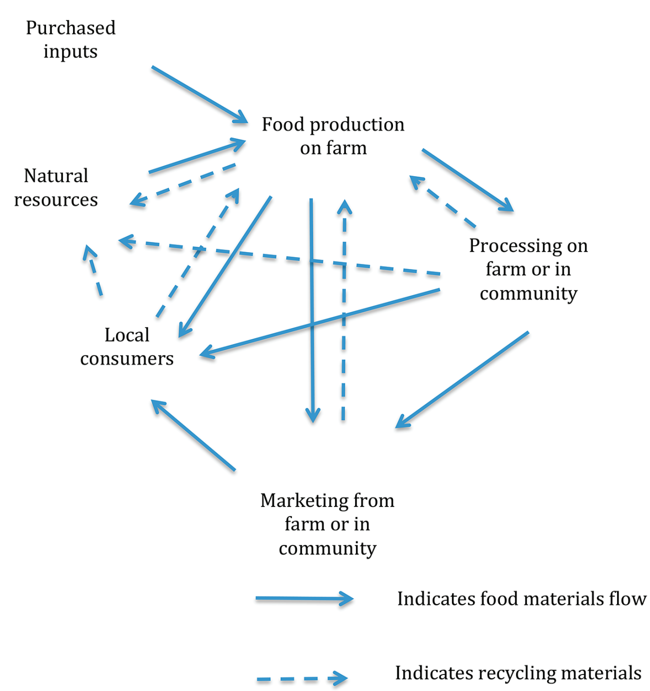


Fig. 3. Local food cycle and food system, a complex and interactive web of processes.

consider essential characteristics of the graduates of the M. Sc. program, and capabilities that will serve students well in a future that will be complex and uncertain. Learning specific skills in farming and details on design that will be relevant today may well be outdated within a short time, while learning to learn will equip our candidates for a lifetime of accessing and interpreting valuable new information. Their multi-dimensional exposure to natural resources, production, economic, environmental and social literature and issues in food systems provides the opportunity to practice and internalize habits that will help maintain an integrated systems focus in whatever activity they pursue in the future. Early in the first semester, we engage students in exercises to help them identify their strengths in learning and in communication, and to find out where there can be improvement. A "learning style assessment" helps people discover their abilities to work as individuals and in teams, how they relate to clients and colleagues in the workplace, and how these skills can be expanded, fine-tuned, and used to advantage. These capacities are valuable across a spectrum of scale from the farm to community, and up to national and global levels. They can be illustrated in a "Learning-Action Web" that suggests how these capacities all relate to each other (Fig. 4).

## Recognize Student Experience as a Key Contribution to Team Learning

Over a century ago, prominent educator John Dewey (1916) insisted that we learn most by incorporating new information into our individual banks of prior experience. To catalyze this process in agroecology we elevate the value of student knowledge and experiences in overall learning in the student-instructor-client community. Validating individual prior experiences begins on our first day, as students and instructors share their personal competencies as well as expectations and motivations in taking and teaching the agroecology course. One of our activities on the first day of class is for each student and teacher to build a brief personal biography to present to the rest of the community, outlining prior education and experiences, travel and learning beyond the classroom, and special talents that can be useful to their teams and to the rest of the class. In essence, each person is identified as an "expert" in some area related to agroecology and the activities in the semester in front of us. This process opens the community dialogue and helps us all become more familiar with the human capital in our learning community, and who to ask about specific technical or social questions–this includes the students' experiences. For example, some students come with strong background in agronomy, and practical experiences others may lack; many students have experiences on farms as World Wide Opportunities on Organic Farms (WWOOFers, http://www.wwoof.net/) or with their own families that are valuable to others in the group. This recognition becomes a source of pride as well as valuable source of information, and draws students into the community as "experts in their own right" in some specific areas of competence. In elevating the profile of each student we can help build personal confidence as well as establish an atmosphere of co-learning in the community (Wiedenhoeft et al., 2015).

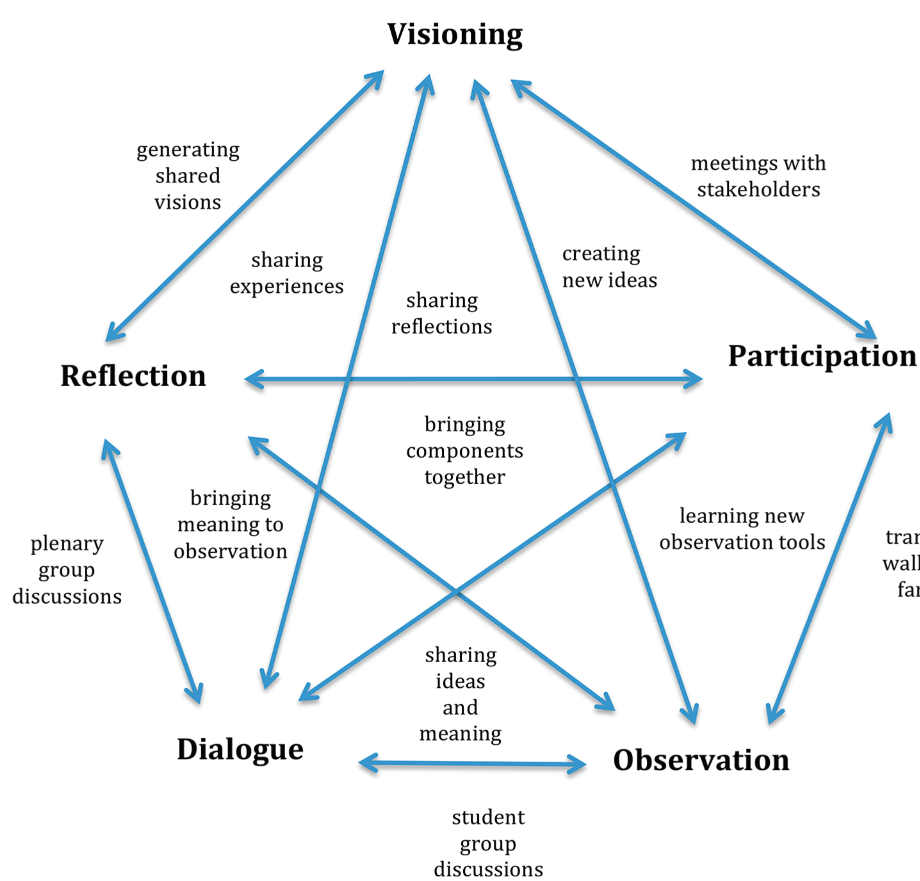


Fig. 4. Capacities of visioning, participation, dialogue, reflection, and visioning developed in agroecology courses and degree programs, including the multiple interactions in a 'learning-action web' of educational activities (from Lieblein et al., 2015).

### Design Learning to Build Capacity for Future Responsible Action

One unique dimension in our approach to teaching is the focus on learning for responsible action (Lieblein and Francis, 2007). Unlike courses that emphasize learning theory and knowledge in specific disciplines, agroecology often encompasses science, agricultural practices and systems design, and social motivation toward meaningful change. While such a broad and socially-oriented focus changes to some degree the intent and potential outcomes of the course and the M. Sc. degree in agroecology, we have found this to be a strong motivator for learning in young people who are idealistic and seriously concerned about making agriculture both efficient in resource use and production, and environmentally sound. We introduce such over-riding issues as social justice, equality of opportunity, and food sovereignty. And we recognize such issues as integral to agroecology education, and not outside activities for those who happen to be socially motivated.

Broad social issues are considered a part of the overall food system, and thus a legitimate area of study as well as individual and group activity. During plenary class discussions and reflections on field experiences we often pose questions such as, how will a given scenario impact the distribution of benefits from a change in the farming or food system? Or for example, if this route of action were implemented what would be the environmental and social impacts on the farm family and rural community? Or given the scarcity of production resources and increasing costs for food, how will this recommendation be feasible in an uncertain economic future? Once students realize that these are really open-ended questions, and that even the instructors do not have all the answers, they become highly motivated to be part of a team that includes their clients and teachers that is seeking answers to some of the most difficult challenges of our time. When we indulge in discussions of ethics and values, and bring in our own opinions as members of the learning community, there may be questions at times from colleagues who ask if we understand the difference between education and advocacy. Our answer could be, "Thank you for that important question, and probably not." If anything, we should all be advocates for learning.

## DISCUSSION AND CONCLUSIONS: DESIGN OF FUTURE LEARNING LANDSCAPES

New educational M. Sc. programs in agroecology in Sweden, Ethiopia, Uganda, and India, modeled after the innovative degree program in the Norwegian University of Life Sciences (NMBU) in Norway and adapted to the curriculum in Swedish University of Agricultural Sciences (SLU) Alnarp in Sweden, represent valuable steps and validation of creative methods for systems education. Successful new programs confirm our observations at NMBU and SLU that this educational strategy is indeed a viable method of teaching and learning. Popularity with students helps explain why agroecology has a growing attraction for graduate study today. The innovations and adoption in other locations represent courageous steps by future-oriented educators to expand the applications and integration of components from current key university disciplines. Our focus on holistic and integrated strategies to investigate contemporary challenges of rural and peri-urban farmers and other stakeholders in the food system brings us all to the cutting edge in research on the largest issues of our time. These challenges include people producing enough food to meet their needs, assuring equity in access to this food, and developing production systems that not only sustain people but also provide ecosystem services and maintain an environment that is healthy for other species.

The concepts, participatory methods, and practical applications have been extended to Uganda Martyrs University and Mekelle University in Ethiopia, with generous support of the Swedish International Development Cooperation Agency (SIDA). There is also an established program at the SLU Alnarp campus in southern Sweden, and a new certificate program at University of Calcutta that began in September 2015. These new programs have attracted quality students who will make a difference in people's lives as graduates return to positions in research and education. Results of impact evaluations have been published in scholarly teaching journals and book chapters (Francis et al., 2013), and widely reported in professional and technical meetings in the Nordic region and elsewhere.

The focus on participatory methods of learning in agroecology places responsibility on students, encourages autonomous learning, and promotes lifelong education, all directions that are well in keeping with the latest ideas in pedagogy. To empower students to assume a greater role in their decisions in education is to prepare them to better deal with the uncertainties and complexities of the future. This requires a change in perspective for both instructors and students, with teachers assuming a broader role as mentors or guides in the learning process and not as primary agents of one-way information transfer. For most of us in education this is a major challenge, as we give up one type of power in the classroom and assume a larger role as catalysts in a meaningful and community learning landscape.

Brazilian educator and philosopher Paolo Freire in his seminal 1968 book in Portuguese *Pedagogia do Oprimido* (Pedagogy of the Oppressed) suggested that this could be called a "pedagogy of no mercy". That has been our experience over two decades, as students are encouraged to challenge their instructors to join in a quest for meaning and truth that is often beyond the comfort zones of everyone in the learning community. Such role changes may be difficult for all, but our experience shows that appropriate changes in methods can stimulate learning, and that is the major goal of education in the university– not putting the spotlight on outstanding orators whose words may be beautiful but are soon forgotten by a passive and non-participating audience.

Our students in the university are those who will carry into the future their knowledge, their skills, their learning habits, and their attitudes and motivation toward solving challenges faced by those less fortunate. Students may be rightfully critical of a well-meaning professoriate they observe as "pale, male, and stale" who become enamored with the details of single disciplines, the precise mechanisms of physiological processes in plants and animals, and the development of farming recommendations that may be quickly outdated by new technologies and systems research. Students can be empowered to challenge our current focus on fine-tuning an industrial agricultural system that is perceived by them as inefficient, overly resource use-intensive, geared only toward profits and not people, beneficial to a few major players, destructive to the environment and many other species, and ultimately non-sustainable.

In the participatory strategies used in our agroecology programs we invite challenges to our points of view, encourage frank and honest discussion of emerging issues, and respect multiple opinions as long as they are well founded on the literature or experience. Such a learning landscape is only for the courageous, both students and teachers, and we must all maintain mutual respect for innovative ideas. The agroecology courses provide safe space for open discussions. We enthusiastically challenge concepts and ideas, as well as visions of the future, while not attacking each other with any degree of disrespect.

In a multi-dimensional communication and information environment where there are multiple sources of data, interpretations, and recommendations for the future, the most valuable role we can play is that of catalyst, sharing some level of wisdom based on experience that is not readily available in a superficial Google (Google, Mountainview, CA) search for literature citations. In a multi-faceted information environment our effectiveness is diminished if we focus on information transfer, providing data and recommendations that will soon be outdated. We should take seriously the idea that "we are drowning in an ocean of data, struggling to stay afloat in a river of information, sifting through a stream of knowledge, and hoping to extract a few drops of wisdom from this huge and chaotic resource" (source unknown). Thus our role as educators in agroecology, and perhaps any of our university disciplines, should be to:

- engage closely with students in the quest to seek meaning
- stimulate enthusiasm and passion for learning for action
- encourage exploration beyond past experience and current comfort zones
- catalyze an open-ended and never-ending quest for the truth

As an interpreter of Thomas Kuhn's seminal book *The Structure of Scientific Revolution* (Kuhn, 1962), philosopher and educator Joel Barker (1993) urges us to explore the ideas that arise around the margins of current society and thought. Kuhn (1962) insisted that change does not happen in the mainstream, where vested economic and intellectual interests tend to stagnate or even ossify to the point where they restrict our thinking and capacity to envision a more desirable future. Barker (1993) berates those who become entrenched in what he calls *paradigm paralysis*, a term that he further defines as *a terminal disease of certainty*. We need to challenge ourselves, our students, our communities, and our society to become a better place, and this often does not imply continued growth in gross national product or accumulation of individual wealth and power. We need the capacity to envision a desirable future, and not succumb to the comfort of trying to adapt and make the best of current directions and priorities that may not help us reach a more desirable and equitable "wanted situation". In the words of humanist and Pulitzer Prize winner René Dubos (1998), "Whenever humans are involved, trend is not destiny".

## ACKNOWLEDGEMENTS

Contributions of colleagues are gratefully appreciated: Dr. Anna Marie Nicolaysen (Norwegian Univ. of Life Sciences); Dr. Suzanne Morse (College of the Atlantic); Dr. Mary Wiedenhoeft (Iowa State Univ.); Dr. Paul Porter (Univ. of Minnesota); and Dr. Robert DeHaan (Dordt College) provided substantial and innovative insight. The paper is adapted from presentations on 1 Oct. 2015 in SLU Alnarp and 2 Oct. 2015 in SLU Ultuna in symposia where Charles Francis received an honorary doctoral degree from the SLU, nominated by co-author Erik Steen Jensen.

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