Multi-Dimensional Thinking: A Prerequisite to Agroecology

[Ch. 1 in *Agroecosystems Analysis*, D. Rickerl & C. Francis, eds. American Society of Agronomy, Madison, WI. 2004. pp. 1-18]

Diane Rickerl, South Dakota State University, Brookings, SD
Charles Francis, University of Nebraska, Lincoln, NE

Agroecology employs the principles of ecology to study, understand, and design agricultural systems. One of the most basic principles of ecology is that changing one component changes everything else. Research and teaching in agricultural science is evolving from using only the conventional cause and effect or linear mentality to a holistic approach focusing on sustainability. A holistic orientation requires a more comprehensive way of looking at things, a more multi-dimensional view. A thought system such as "Multi-Dimensional Thinking" is not linear, or even circular, but spherical plus a time dimension. The evolution to this approach is the result of a natural progression in understanding complexity, and even a logical developmental process. Such thinking provides a framework or context into which component technologies can be organized. It is important to define multi-dimensional thinking and provide examples from different areas of study, or windows on the agricultural system, that we call disciplines. In conclusion, we discuss multi-dimensional thinking as it relates to Agroecology.

What is Multidimensional Thinking?

Multi-dimensional thinking is difficult to achieve in our discipline-specific departments. In some ways we are like the six blind fellows in the poem by John Godfrey Saxe, "The Blind Men and the Elephant" (Untermeyer, 1963). Each suffers from the same handicap (each in a specific discipline), and each approaches a different part of the elephant (specialization). The poem points out that reductionist thinking, even by wise people, does not often give us the complete picture. Each of the wise people was partly in the right, but all in the wrong, in terms of the larger structure and function. These specialists demonstrate that the description of the parts cannot possibly give the whole picture, and that linear thinking is sometimes inadequate. The large creature we are trying to understand is agriculture, and the innovative, multi-dimensional approach described in this book is Agroecology.

Multi-dimensional thinking may be considered a prerequisite to the development of agroecology. A narrow focus helps us become more specialized and productive in our disciplines, yet may have narrowed our field of vision until we become like the blind men in the poem with respect to wider issues in agriculture. Since we often relate dimension to the visual arts, construction projects or geometry, it is useful to begin with several visual, concrete examples. First, some regional artists from the Midwest.

Czestochowski (1981) described Grant Wood as an artist who "gave expression to a living experience" and whose "art narrates the frenzied transformation in American values from those of a rural community to those of an urban-industrial society…reaffirming the uniqueness of American culture as a social and environmental phenomenon". Wood mastered the illusion of dimension. It is easy to see the differences in dimension among Grant Wood's paintings. "Plowing on Sunday," with only the farmer in the foreground, is uni-dimensional (Fig. 1); “American Gothic” is a 2-dimensional presentation of the farmer and his wife in the foreground and a farm house with a Gothic window in the background (Fig. 2); and “Stone City” (Fig. 3) is a 3-dimensional view that carries the eye for miles across the Iowa countryside. These differences in dimension are perceptions created by the artist.

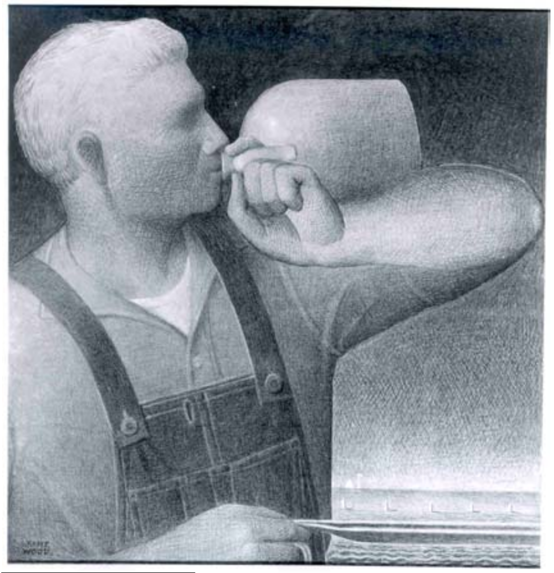
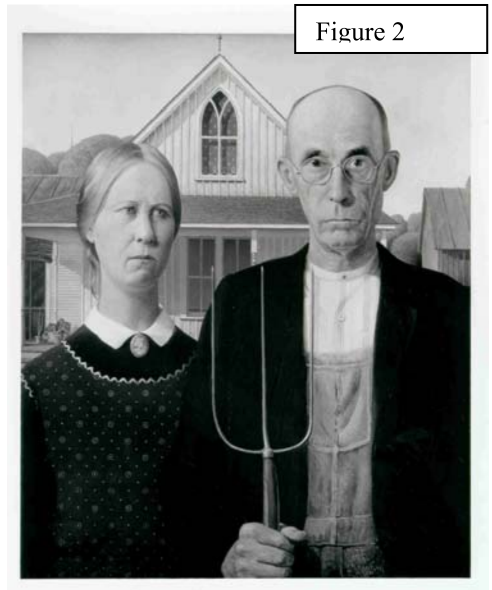


Figure 1

Visual artists can take another step and create relief or sculptures that exist in space as multi-dimensional works. Christian Petersen’s sculpture “The Cornhusker” (Fig. 4) depicts a young man from Nevada, Iowa who has won the county, district, and state husking championships. Bliss (1986) describes the sculpture as “Petersen’s tribute to a uniquely Midwestern type of athlete in the premechanized farm era.” South Dakota has one of the nation’s most famous relief sculptures, Mount Rushmore. The viewer is consumed by the immense life-like faces of four presidents. An even more immense mountain sculpture of Crazy Horse is moving toward completion a few miles to the south. The use of real dimension, and in these examples, scale, adds to the impact, and their historical relevance adds a fourth dimension of time.

In the 1960s, sculptors started to create environments as their 3-dimensional work. The impact of works such as “The Farm Worker” (Fig. 5) by George Segal, which include life size sculptures in a created space, comes from the total environment created by the artist. Segal (Seitz, 1972) commented about one of his works, “I was responding to all the polarities, and had to find a way to connect real space, direct sensation, with a metaphysical dream state. Specific and general had to become entangled; figure and abstraction had to fuse.”

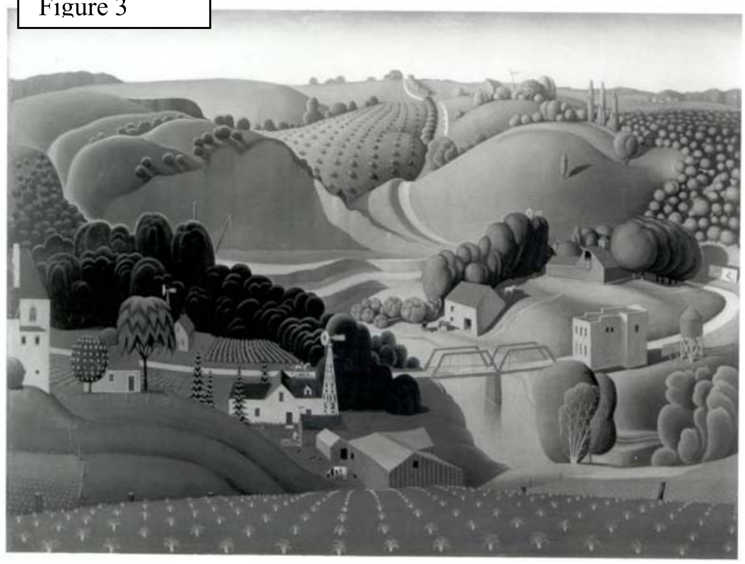
Figure 2



In the study of geometry, dimension is defined and drawn. Students first learn the definition of a point, then a line, a plane and a solid. The concept of volume is not taught before the concept of area, as that would not be a logical progression. For most of us, multi-dimensional thinking has progressed through our personal development and education, just as we learned the details of geometry. In contrast, most courses packaged within disciplines require us to pull back into thinking about components of systems, thus address challenges in fewer dimensions. It is difficult to assemble the pieces of a puzzle if each has been modified or fine-tuned without doing this within the context of the larger picture.

In Piaget's studies (1973) of intellectual development of children he states, "I will call it psychological, the development of the intelligence itself – what the child learns by himself (sic), what none can teach him and he must discover alone; and it is essentially this development which takes time." Piaget describes sequential stages of development that proceed from concepts of substance as an empty form to conservation of weight and finally to conservation of volume. This developmental progression is analogous to the concepts of point, line, plane, and volume in the principles of geometry. However, agricultural systems are far more complex, and involve the interaction of many biological and physical factors, plus human ambitions and survival within the natural and the built environments. Kirshenmann tells us in chapter eleven (Ecological Morality) that philosophers, sages and shamans have understood that humans are part of a complex web of life. Our only chance for understanding how systems function, and how our component data fit in, is to embrace this complexity, and for some of us to look carefully at whole systems.

Figure 3



Conceptual development is often expressed visually in the progression of a child's drawings, going from dots and slashes, to enclosed shapes, to recognizable forms (Fig. 6). All of us have seen the lack of perspective (dimension) in children's drawings where trees and houses sit on the horizon line. Even projects built from modeling clay (a 3-D media) often take on a 2-dimensional quality in the hands of a young child. Piaget (1973) summarizes,

> *"This order of succession shows that, if a new instrument of logic is to be constructed, there must always be previous logical instruments, that is the construction of a new notion will always suppose substrata, previous substructures, and this by indefinite regressions."*

The medium, modeling clay, cannot be used in 3-dimensional expressions until the concept of volume has been developed. To suggest that research on component technology is more "childlike" would be highly erroneous – in fact it may be the systems integrators who need to revisit this concept of how appreciation of spatial dimension develops. Perhaps those unencumbered by heavy, component-oriented detail are better able to grasp the larger issues?

Our understanding of geography is an excellent example of the progression of multi-dimensional thinking. By the time of Christopher Columbus, there had been a great deal of change in perceptions about the earth. The local "point" focus of prehistoric humans in their tribal territories progressed to a broader 2-dimensional theory of a flat earth. With some evidence and multi-dimensional hopes, Columbus began his voyage across the ocean. Even though he didn’t know where he was going, or where he had been when he returned, Columbus’ dimensional perception had been enhanced and ideas began to change. In 1969, when Neil Armstrong walked on the moon as the world watched, multi-dimensional thinking took a giant step through both space and time.

Leonardo da Vinci was an Italian artist and scientist, one of the first "renaissance men" and an excellent example of a person with multi-dimensional thinking. Best known for his classical paintings, Leonardo was architect, engineer, anatomist, and sculptor. Today's university would have difficulty finding a department or even a college where his immense talents would fit into the confines of one discipline.

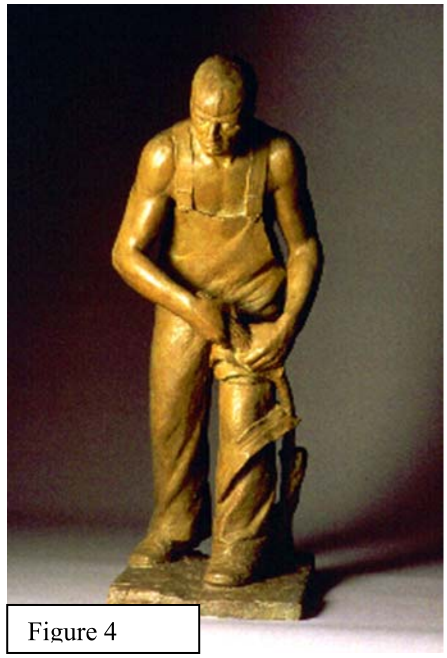


Figure 4

In biological science, an example of multi-dimensional thinking can be visually illustrated through advances in the development of the microscope. Robert Hooke writes in *Micrographia* (Espinasse, 1956) “…these pores, or cells, were the first microscopical pores I ever saw, and perhaps that were ever seen…” His discovery was named the “cell” because only the lines of the cell wall were visible using his microscope (Fig. 7). Hooke was a multi-dimensional thinker. He was accomplished in science, art, and engineering. Hooke’s friend Wren (Espinasse, 1956) writes, “of him I must affirm, that, since the time of Archimedes, there scarce ever met in one man, in so great a perfection, such a Mechanical Hand and so Philosophical a Mind”.

With further development, the microscope revealed cell contents as well as cell walls (Fig. 8). The scanning electron microscope added the third and fourth dimensions to microscopy (Fig. 9). Today we can watch cells function and follow their life cycles over time using technology that has progressed from uni-dimensional to three and then four-dimensional. As in the case of Piaget’s intellectual development, each phase in the development of the microscope built on the previous technology and understanding, and would have been impossible without it.

Computer technology is perhaps today’s most rapidly changing example. Computers initially processed numerical data. Before long they could use instructions to plot or chart data, then create surfaces and moving 3-dimensional images. Virtual realities generated by computers today can take us through experiences that are multi-dimensional. In this case a sense of reality is gained from the combination of visual, audio and tactile experience. Perhaps we should be grateful that development of computer imagery has been spurred by the military and by action video games, and that these advances may soon be applied for more beneficial uses in society. Technology has allowed the enhancement of sensory perception. It is the illusion of an environment, the same concept used by Segal.

These examples of the progression of multi-dimensional thinking indicate changes in perception through time. Our perception of time itself has also evolved. In the ancient Mayan culture it was believed that humans were placed on earth to bear the burden of time, to be the timekeepers. Einstein in his special theory of relativity regards the time-variable as a Euclidean 4-dimensional continuum. In the words of Niels Bohr (Clark, 1971), "Mankind will always be indebted to Einstein for the removal of the obstacles to our outlook which were involved in the primitive notions of absolute space and time." The Mayans, Columbus, Neil Armstrong, Hooke and Einstein are just a few examples of Dimensional Thinkers. Why are they the exceptions?

There are many obstacles to multi-dimensional thinking. We have discussed limitations in technology, society, university department organization, and self. Microscopes and computers have changed our perceptions and given us new insights. Societies and their religions have been obstacles to creative and multi-dimensional thinking. Popular belief in the 1400s said that the world was flat. Columbus' theories were rejected in Portugal and initially in Spain. Only his persistence led to his success. When Einstein proposed that the energy contained in a light beam is transferred in quanta, he contradicted a century-old theory. Almost no one accepted the new proposal. Even when Robert Andrews Miliken experimentally confirmed the theory a decade later, he was surprised and uncomfortable with the outcome. Darwin was extremely cautious in explaining his theories on evolution to the public, often sitting on his results for five years or more. He would also have found difficulty making tenure in universities today. The views of society, including the university community, can be a strong limitation, but society can progress just as the individual progresses through developmental stages.

Figure 5

Thomas Kuhn (1996) takes the argument further, suggesting that evidence contrary to our predominant paradigms can be virtually invisible to the observer. This is why change occurs on the fringes, and rarely in the mainstream (Barker, 1985). Rachel Carson's (1962) Silent Spring attacked the widespread use of pesticides and precipitated a radical change in agriculture, but this was only possible because of her biology background and ability to see the larger picture.

Agroecology requires multi-dimensional thinking, or the ability to see the whole elephant as well as the context in which it functions. The examples given illustrate the importance of an individual's psychological development in his/her ability to think in multiple dimensions. The importance of society and the prevailing views are also instrumental in shaping science and our understanding of systems. Technology can offer tools to speed the development of dimensional thinking, but in itself it is not necessarily multi-dimensional. It takes a unique individual or society to defy the current theories of culture and/or science to pursue different views.

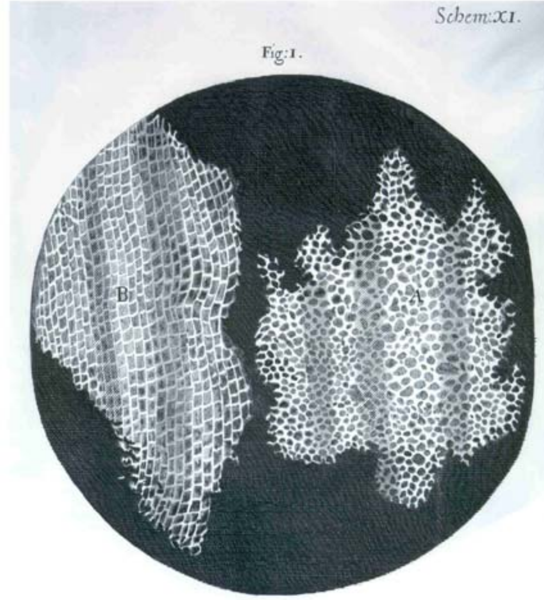


Figure 7

Pursuing a Multidimensional View of Agroecology

Agroecology has been variously defined as the marriage of agriculture and ecology, the understanding of crop ecology in the context of cultivated systems, and the description of agriculture in ecological terms. Gliessman (1998) traces the history of uses of this term back to the early part of the 20th Century, when field ecology and practical agronomy shared common interests in cultivated and natural systems. Crop ecology was an important area of study until ecologists moved toward greater focus on natural systems, and agronomists became more specialized in disciplines related to specific components of the system. The Gliessman chronology has been expanded to include more references from Latin America and Europe in a recent article on defining agroecology as the ecology of food systems (Francis et al., 2003).

What are the dimensions contained in an agroecological view and what approaches can be taken to reach the broad and needed level of understanding? Okigbo (1989) lists five elements that should always be considered for a sustainable food system in a given area, to which we add a sixth dimension related to the environment.

- **physiochemical factors**, soils, climate, moisture, radiation, day length
- **biological elements**, crops animals, pests
- **changing and appropriate technologies** available to the farmer
- **sociocultural background**, education, policy, experience
- **economic viability,** market, costs, management
- **ecological soundness**, preservation of biodiversity and ecosystem functions.

Okigbo emphasizes that these dimensions should each be considered for sustainable development at the global, regional, national and local level. Further discussion of the importance of hierarchy and scale is found in Chapter 2.

Harwood's (1990) history of sustainable agriculture suggests two reference points for the evolution of this concept. The first is "agriculture based on principles of ecological interaction" which emerged in the early 1980's and the second is "stable agriculture in the global sense, involving all facets of agriculture and its interaction with society" which emerged later in the decade. Harwood's own definition, given certain limitations, is "an agriculture that can evolve indefinitely toward greater human utility, greater efficiency of resource use, and a balance with the environment that is favorable both to humans and to most other species." The definition incorporates values, but allows for agricultural development. Harwood reviews a thought development process (multi-dimensional thinking), of major significance to the concept of sustainability. From this process, stemming from the early 1900's, there is

- the interrelatedness of all parts of a farming system, including the farmer and his family
- the importance of the many biological balances in the system

- the need to maximize desired biological relationships in the system and to minimize use of material and practices that disrupt those relationships.

In the late 1900's, as communication and transportation technology enabled global exchange, we began to realize the role of human diversity and community in food systems. Butler and DePhelps (1995) discuss the development of rural and urban communities in America. Their sequence fits the progression from point to sphere to time in multi-dimensional thinking. The "point" is characterized by many small rural communities located in a specific geographic place. Technology allowed interactions between communities with shared interests (linear) as rural communities began to decline. In the 1990's bioregionalism (circular) emphasized the interconnectedness within a geographic region and the idea that cultural identity is connected to the natural environment.

In a sense, bioregionalism is a shift of emphasis from national or global to local communities within a specific geographic region. This shift does not ignore the relationships between local and global spheres. Rather, it focuses energy within local communities while strengthening relationships between communities, within regions and beyond.

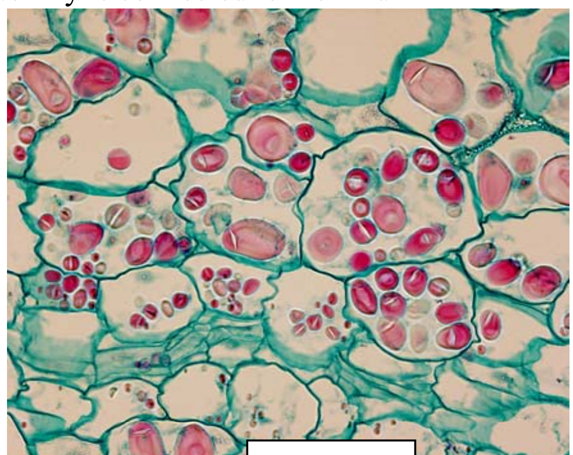


Figure 8

In this view, bioregionalism can become fully dimensional, looking at relationships among interacting spheres. The bioregion becomes a common ground for effective community-based problem solving (multi-dimensional thinking). Further, the relationships among these communities develop and evolve over time, changing in response to demographics, resources, and political circumstances among other factors.

To encourage community member participation a well-developed sense of place is needed. "To know the spirit of a place is to realize that you are part of a part and that the whole is made of parts, each of which is whole. You start with the part you are whole in". Butler and DePhelps (1995) offer approaches for developing what is essentially an agroecological view for community-based problem solving. They suggest techniques and provide examples of strategies that encourage open dialog and create trust among community members.

A recent commentary article proposes the broader definition of agroecology as the "ecology of food systems" (Francis et al., 2003). In this article we suggest that agroecology is an appealing term that helps scientists, farmers, and others focus on both the structure and function of agroecosystems, including the long-term positive and negative impacts of systems on humans and other species. Although focus in agricultural science and current agroecology courses has been primarily on the production components and environmental impacts, Francis and colleagues argue that attention to processing, marketing, and consumption dimensions will help in understanding the total energy and materials flows in the system and lead to design of more efficient resource use and human utility in the systems. One goal of their article is to stimulate teachers and researchers in agroecology to embrace this broader concept of studying the total food system, and thus to add multiple dimensions to our understanding of how systems function and how they can be improved.

Potentials for Agroecology in Universities

The results of a survey of land grant universities conducted by Francis et al. (1995) suggest that, "There is great potential for cooperative ventures among universities to address both the sustainability of agriculture and the concerns of society." Although most of the current business as usual takes place within the confines of discipline-specific departments, there are multi-discipline centers and areas of concentration in teaching that demonstrate how new approaches can be implemented within the current system. A list of potential future directions focuses on forming/strengthening coalitions and improving communication networks that bridge the traditional boundaries and create new communities of scholars who can deal with complex issues.

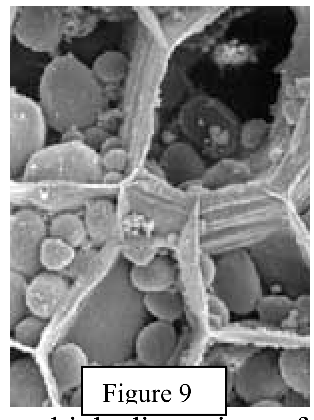


Figure 9

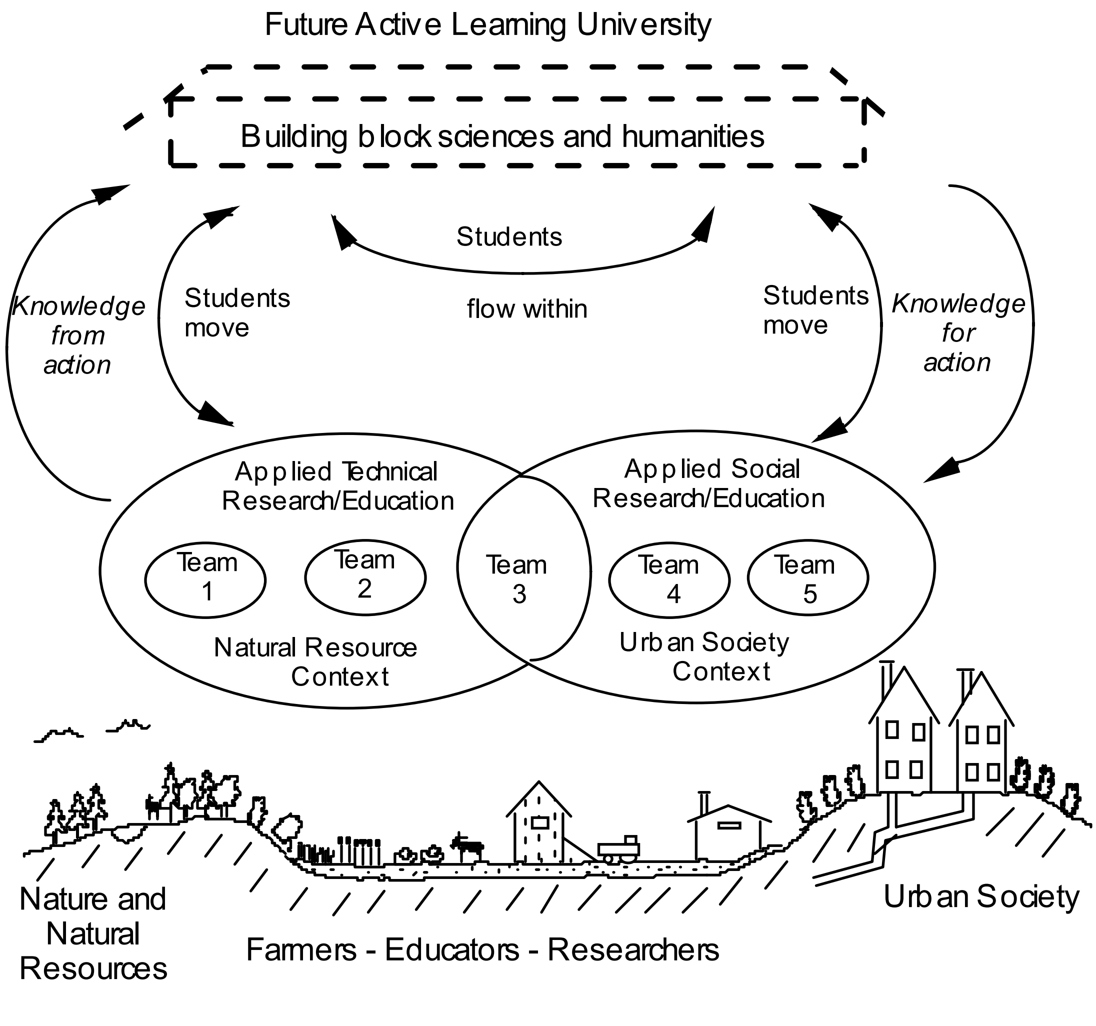
Student demand for education in agricultural systems in the U.S. and in ecological agriculture in the Nordic Region has stimulated the search for new approaches to organizing learning. Lieblein et al. (2000) present a critique of the current university structure that places all activities in boxes that correspond to courses in specific topics, too often taught in isolation from other courses and from the operating world of agriculture. They point out that today's society is beginning to demand that ecological, ethical, and social dimensions must be included in our design of food systems and in shaping the future of agriculture. If the agricultural universities are unable to respond to the need for students to understand complexity and the multiple dimensions of tomorrow's food systems, it is likely that other players will enter the educational arena (Kunkle et al., 1996).

Lieblein et al. (2000) suggest that universities' curricula are based on the assumption that there is a large gap between ignorance and knowledge, while in reality there is a much larger gap today between knowing and doing. For this reason, they recommend active learning based on student projects and greater emphasis on activities outside the classroom. Their concept of a "future learning university" is shown in Fig. 10. An expanded definition of faculty to include people from business, government, and farming can enhance the classroom education, recognizing that students learn in many ways and in different settings. (Francis et al., 2003). These concepts are being introduced in the Nordic graduate programs in agroecology and ecological agriculture, the term use in that region to describe organic farming.

Multiple Dimensions of Agroecology

This book explores the many dimensions of agricultural systems that are needed to fully understand how they are structured and how they work. It is convenient to approach the system at different spatial levels, in order to understand the dynamics of biological and geochemical reactions that occur there. It is essential to focus on the foundation of soil and climate to understand how these set limits on potential productivity of systems. Yet equally important are the human participants in the system and how they design and manage resources to extract food and other products from the agroecosystem. It is the multi-dimensional view of these different levels that make this book unique.

Fig. 10. Schematic description of future university for active learning and research, with student and faculty learning activities often in the farming environment, and close relationships with both natural resource and urban society contexts (from Lieblein, Francis, and King, 2000; reprinted with permission of *Journal of Agricultural Education & Extension*, Wageningen, Netherlands).



The types of structure and the processes that occur at different levels in the spatial hierarchy are described in Chapter 2. The functions of an agroecosystem cannot be well understood unless this is viewed from different points of view, and this requires a multi-disciplinary approach and analysis of system functions. Soil dynamics and plant nutrition are at the foundation of system potential, and our understanding of these processes is growing as we study the biological complexities of soil organisms and nutrient interactions unconfounded by massive applications of fertilizers and pesticides (Chapter 3). Insects, weeds, and pathogens interact with crops and animals at the field and farm levels to influence success of the agricultural enterprises, and the complexity of these processes is discussed in Chapter 4. The aggregation of functions of individual crop plants and domestic animals leads to study of the whole farm, and how its dynamic nature can be directed through alternative approaches to management (Chapter 5).

Economics can be used to evaluate agricultural systems in multiple ways. The neoclassical approach to economic analysis is but one method of evaluating success, and a multi-faceted approach to measurement is presented in Chapter 6. The importance of social capital and the dynamics of rural communities are discussed in their many dimensions in Chapter 7. How the development of systems contributes or detracts from the conservation of resources is presented in Chapter 8. Global information systems are extremely valuable in assessing the spatial variability of many dimensions of agricultural systems, and over time can provide a dynamic picture of how these change (Chapter 9).

An emerging interest in agriculture is the multifunctionality of rural landscapes, and how society recognizes and rewards the ecological services these landscapes provide. Methods of measuring ecological functions are presented in Chapter 10. Including humans and their activities as key drivers in the design and function of agricultural systems brings in ethical dimensions of agriculture, including how we treat the landscape, its resources, and each other. These are discussed in Chapter 11. The future of agroecology as it relates to better understanding and design of food systems is explored in Chapter 12, including a summary of the conclusions from the preceding chapters.

The evolution of agriculture in America brings us to a time that is the right time for using the concepts and tools that are emerging in our expansion of the field of Agroecology. The complex problems facing our global society with local and regional food shortages and environmental degradation will require approaches that integrate the environment, society, and ecology. We are being asked to develop a new ethic for agriculture, an ecological morality that will reflect our understanding of nature. Community-based problem solving and change within the landgrant universities are approaches that can be used. Regardless of the approach, our way of thinking has to be multi-dimensional.

REFERENCES

Barker, J.A. 1985. Discovering the future: the business of paradigms. ILI Press, Lake Elmo, MN.

Biel, T.L. 1990. Atoms building blocks of matter. Lucent Books, Inc., San Diego.

Bliss, P.L. 1986. Christian Petersen remembered. Iowa State Univ. Press, Ames.

Bulter, L.M., and C. DePhelps. 1955. Human diversity, community, and viable food and agricultural systems. p. 161-193. *In* R.K. Olson, C.A. Francis, and S. Kaffka (ed.) Exploring the role of diversity in sustainable agriculture. ASA, Madison, WI.

Clark, R.W. 1971. Einstein, the life and times. The World Publishing Company, New York.

Espinasse, M. 1956. Robert Hooke. Univ. of California Press, Berkeley.

Czestochowski, J.S. 1981. John Steurat Curry and Grant Wood, a portrait of rural America. Univ. of Missouri Press, Columbia.
Francis, C., G. Lieblein, L. Salomonsson, J. Helenius, T.A. Breland, D. Rickerl, N. Creamer, R. Salvador, M. Wiedenhoeft, S. Simmons, P. Allen, S. Gliessman, M. Altieri, J. Porter, R. Harwood, C. Flora, and R. Poincelot. 2003. Agroecology: The ecology of food systems. J. Sustainable Agriculture (in press).
Ginsburg, H., and S. Opper. 1969. Piaget's theory of intellectual development, an introduction. Prentice Hall, Englewood Cliffs, NJ.
Harwood, R. 1990. A history of sustainable agriculture. p. 3-19. *In* C. Edwards, R. Lal, P. Madden, R. Miller, and G. House (ed.) Sustainable agricultural systems. Soil & Water Conservation Society, Ankeny, IA.
Kuhn, R. 1996. The structure of scientific revolutions, third edition. Univ. Chicago Press, Chicago.
Kunkle, H.O., I.A. Maws, and C.L. Skaggs (ed.) 1996. Revolutionizing higher education in agriculture. Iowa State Univ. Press, Ames.
Lieblein, G., C. Francis, and J. King. 2000.Conceptual framework for structuring future agricultural colleges and universities in industrial countries. J. Agricultural Education and Extension, 6(4):213-222.
Okigbo, B. 1989. Development of sustainable agricultural production systems in Africa. Based on the first lecture in the Distinguished African Scientist Lecture Series delivered at IITA, Ibadan, Nigeria on 26 April. 66pp.
Piaget, J. 1973. The child and reality. Grossman Publishers, New York.
Seitz, W. 1972. Segal. Harry N. Abrams, Inc., Publishers, New York.
Tuchman, M., (ed.) 1967. American sculpture of the sixties. Los Angeles County Museum of Art, Los Angeles, CA.
Untermeyer, L. 1963. The golden treasury of poetry. Golden Press, New York.

Figure Captions

Fig. 1. Grant Wood, *Plowing on Sunday*, 1934, ©Estate of Grant Wood/Licensed by VAGA, New York, NY. Museum of Art, Rhode Island School of Design, Gift of Mrs. Murray S. Danforth.

Fig. 2. Grant Wood, American, 1891-1942, *American Gothic*, 1930, oil on beaverboard, 74.3 x 62.4 cm, Friends of American Art Collection, All rights reserved by The Art Institute of Chicago and VAGA, New York, NY, 1930.9341, reproduction © The Art Institute of Chicago.

Fig. 3.Grant Wood, *Stone City, Iowa*, 1930, (JAM.1930.35), Joslyn Art Museum, Omaha, Nebraska.

Fig. 4. Christian Petersen (American, 1885-1961), *Cornhusker,* 1941. Painted plaster, 43 x 16 x 24 inches. Christian Petersen Collection, Brunnier Art Museum. University Museums, Iowa State University. Gift in memory of Joseph M. Coppola, Sr., by the Coppola Family. UM99.329

Fig. 5. George Segal, *The Farm Worker,* 1962-63, ©The George and Helen Segal Foundation/Licensed by VAGA, New York, NY.

Fig. 6. Children's drawings showing the progression in conceptual development.

Fig. 7. Robert Hooke's representation of cork cells, *Micrographia: or Some Physiological Descriptions of Minute Bodies Made by Magnifying Glasses,* London, 1665. Courtesy of Smithsonian Institution Libraries, Washington, DC.

Fig. 8. Transmission electron micrograph of potato cells with starch granules. Courtesy of Michael W. Davidson.

Fig. 9. Scanning electron micrograph of potato cell with starch granules. Courtesy of Institute of Food Research, United Kingdom.

Fig. 10. Schematic description of future university for active learning and research, with student and faculty learning activities often in the farming environment, and close relationships with both natural resource and urban society contexts (from Lieblein, Francis, and King, 2000; reprinted with permission of *Journal of Agricultural Education & Extension*, Wageningen, Netherlands).