# Southern Resilience and Sustainability
# Chapter 1
# Basics of ecological resilience

We all want to survive, grow and prosper. All life does. All living beings strive to survive and reproduce. To do so, every species, every individual, faces challenges which it must overcome. Lack of resilience to a disturbance can wipe out a crop, a farm, a community, a nation or a species. The cause can be climate change, economic crisis, resource depletion or innumerable other forces.

When societies, farms or our food supply seem stable, cultures including ours often neglect resilience. The magnificent creations of mankind often pull us far from the resilience which insures survival and reproduction. When any species neglects resilience, it collapses and disappears. This has happened to thousands of species, societies, communities and farms throughout man's time on Earth. Will it happen to ours? How can we keep that collapse from happening? Or, how can we manage that collapse, when it comes, so it will result in a more resilient society or farm in the future?

Answering these questions has become easier with the advent of ecological resilience research. The rise of this research has been accompanied by huge outpourings of research in psychological resilience and sustainable systems research.

We seek to unite these research areas to assist communities, farmers and governments in creating more resilient systems. But what *is* a resilient system?

**Resilience 101**

The resilience of a system, individual or society is defined as its ability to respond and recover from disturbance. A system lacking in resilience collapses upon disturbance, without the capacity to reorganize itself. Whether it's a civilization, modern corporate power, government, forest, or farm, each system responds to disturbance in ways that increase or decrease resilience of the system.

**Engineering vs ecological resilience**. Early in the study of resilience, C. S. Hollings[3] made a key distinction between our everyday concept of resilience, what he called engineering resilience and ecological resilience.

Engineering resilience means bouncing back, returning to the original condition, form, or function. Materials engineered to be resilient are those which withstand stress, recover from disturbance, and return to the original form, exactly as it was before. In computer programming, mechanical engineering or robotics this is imperative as the original form is required for the system to work.

Such engineering resilience is incorporated in ecological resilience, but we go one step further. Ecologically resilient systems recover from disturbance by adapting and changing from the original form.

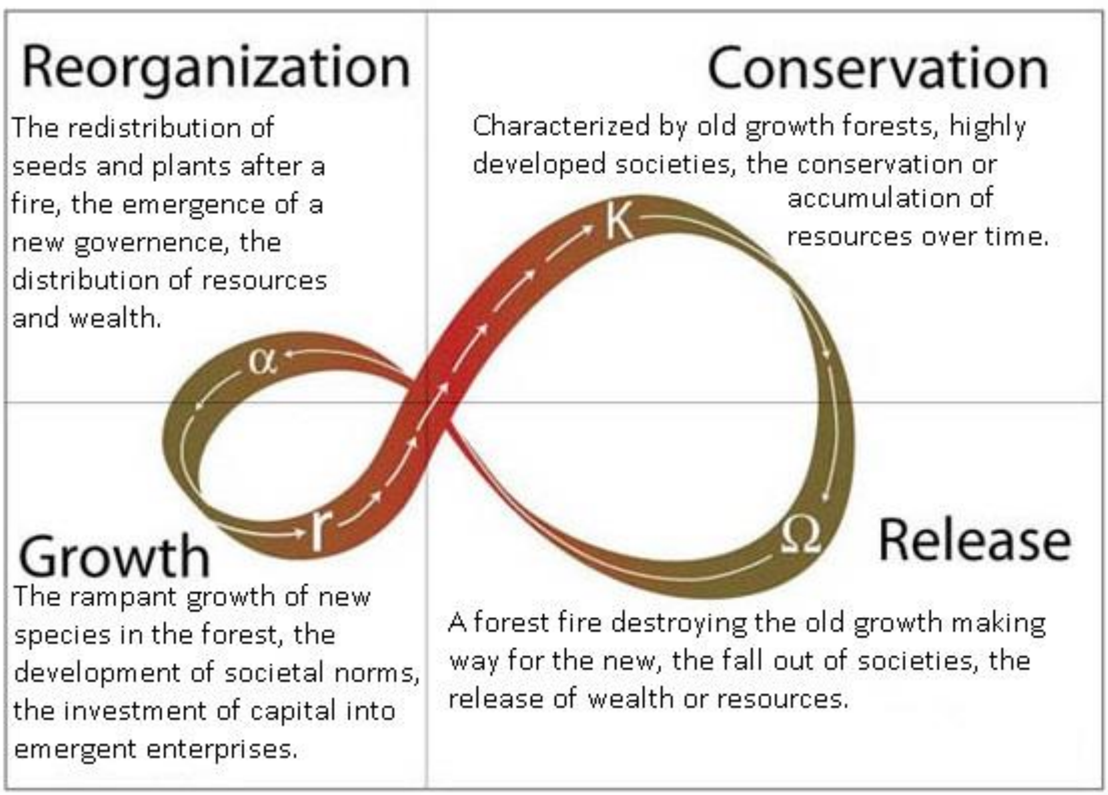
[3] Hollings, C.S., 1973. Resilience and stability of ecological systems. Annual Review of Ecology and Systematics, 4:1-24; Holling, C.S. 1996. "Engineering Resilience versus Ecological Resilience." National Research Council. Engineering Within Ecological Constraints. Peter Schultz, Ed. Washington, DC: The National Academies Press, 1996.

Sometimes this adaptation develops into something better, more efficient or more capable of responding effectively to the next disturbance. Sometimes adaptation can develop into systems that are worse off than they were before, stripped of resources, and too disorganized to develop into a robust ecosystem.

Often this heightened disorganization occurs in the wake of disturbance as the result of a system that went too long without disturbance, holding onto too many resources, trapping them from the continual adaptive cycle at work in all natural systems. Whether it is an old growth forest grown too dense and at risk of massive catastrophic forest fire or a flood plain left dry too long, ecosystems need to be disturbed to unlock resources and promote new growth through the adaptive cycle.

**The adaptive cycle** – at the center of ecological resilience – has four stages**: rapid growth (r), conservation (K), release (Ω) and reorganization (α)**. As a rule the cycle flows from one stage to the other from release, to reorganization, to rapid growth, to conservation and back to release. This is not always the case since managed systems can become sensitive and responsive to the stages of the adaptive cycle. In a large company, a CEO, manager, or astute employee may observe that the company has too long been in a conservation phase, at risk of a potentially hazardous release and reorganization. Through this observation a series of changes can be made in the company to proactively reorganize to either curtail or avoid entirely the risks of an omega, or release phase.

In nature, without the assistance of a land manager the adaptive cycle is constantly ebbing and flowing, systems building up and breaking down at multiple levels within the same ecosystem. Observance of any ecosystem over time reveals a succession of communities following these stages.



Ecological resilience describes the change in our land as a series of adaptive cycles. Let's look at the "climax" oak-hickory forest which maintains itself in the **conservation** phase until being disrupted by the family of beavers in the **release** phase. The pond left by the beavers immediately begins to transform in the **reorganization** phase as it accumulates organic matter, is invaded by various pond organisms and rapidly accumulates carbon, developing into more and more complex structure in another **growth** phase. Gradually the accumulation of organic matter results in a taking over of bog organisms and eventually a meadow and then a forest; the **conservation** stage in many natural ecosystems

**Human application of the adaptive cycle.** American Indian tribes used the adaptive cycle to their advantage as we use it today to clear brush and overgrown fields. Tribes would use fire to clear dense forest into savannahs for hunting grounds or to clear shrubs from meadows for agriculture. Through inducing a release phase for shrubs they prompted brief growth and conservation phases for grasses and forbs. Soon invasion by shrubs prompted another burning, or release, followed by another reorganization, growth, and conservation phases.

> Tillage is a disruption of existing systems, allowing organization and growth of a new system. Whether ecological resilience is increased or decreased depends on the qualities of the system. Various approaches and considerations on tillage are explored in more depth in the ecological integration chapter.

Another example can be seen in standard plowing of fields. Plowing disrupts an existing network of soil flora and fauna which is often a very resilient system. Plowing is also a release for grasslands, triggering the adaptive cycle for various successions of productive crops. However, since soil is so often depleted by erosion after plowing, the system can decline to a lower level of productivity, though still exhibiting every phase of the adaptive cycle. Continued loss of soil resources–especially when combined with disturbances such as drought–eventually lead to desert or barren rock.

In managing ecosystems, man is often pitting one adaptive system against another. This process also occurs throughout nature. A continued challenge for researchers is to understand how these adaptive cycles are effected by the complex systems which are continuously adapting to each other. Because there are so many complex adaptive systems constantly at work within a single ecosystem continually affecting the pattern of the adaptive cycle, the result often seems chaotic, much like the booming, buzzing confusion we all face as infants. Our tasks is to help you make sense of this chaos.

**From systems analysis to chaos theory, complexity, and complex adaptive systems**. All living systems are complex adaptive systems: complex because they have many parts and many connections between the parts; adaptive because they respond to changes in ways that promote survival and reproduction.

Jan Christian Smuts, a Prime Minister and General in South Africa began systems theory when he created the term holism[4]. Smuts' approach is most continuous in agriculture with the practical systems work of Holistic Resource Management[5] begun in Zimbabwe. However, as von Bertalanffy[6] makes clear in his classic General Systems Theory, much of the work labeled systems has little in common with Smuts and Savory's work. The Aristotelian "the whole is greater than the sum of the parts" is the sense

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[4] Smuts, J.C., 1926. Holism and Evolution. London: Macmillan.
[5] Savory, A., 1988. Holistic Resource Management, Island Press.
[6] Von Bertalanffy, L., 1968. General Systems Theory. New York: Braziller.

in which farmers use the term "systems." The system is an emergent whole with properties not present in its components.

Many researchers understand the components they study as systems, but lack an understanding of the larger systems which determine the activities of the component they are researching. Academically-oriented researchers are often reflexively reductionist. When confronted by a system, they try to break it down into components to explain the system. Many researchers have been very successful at controlling defined systems by being reductionistic. Within this tradition, overly mechanistic academics have adopted systems language and created something called "systems analysis."

Systems analysis is defined largely in terms of quantification of components, simulation and optimization of mathematical models and algorithms. World War II was an impetus for development of quantitative approaches for making decisions regarding allocation of scarce resources. The tool of linear programming and the field of operations research (OR) resulted. In the euphoria after the war, OR evolved into system analysis with de facto headquarters at the Institute for Advanced Study at Princeton University under the leadership of John von Neumann.

Initially, von Neumann and other systems analysts believed that if only enough computing power could be arrayed to fully describe the components and initial conditions in sufficient detail, any complex phenomenon (such as the weather) can be predicted and controlled. Systems analysts had blind faith that if we can't predict a complex phenomenon, we just need more computing power and we will eventually understand it. However, just as he was early to appreciate the power of computers, von Neumann was also early to question his former steadfast faith in quantitative, algorithmic understandings of Nature.

> "*Just as Greek and Sanskrit are historical fact and not absolute logical necessities, it is only reasonable to assume that logic and mathematics are similarly historically accidental forms of expression . . .[W]hen we talk mathematics we may be discussing a secondary language built on the prime language used by [Nature].* " [7]

This "prime language of Nature" is focused on open systems, the class to which all living systems belong.[8] Algorithms and mathematical models required for systems analysis work best in closed systems. Typically, they cannot function in open systems. For any algorithm or model to function, the types of inputs are specified. Random or novel input is not allowed. All adaptive life must be drained from inputs and from the system itself. Chaos theory was an early effort to overcome these limitations.

**Chaos theory** entered the popular imagination with a bestselling 1987 book[9] though both Lorentz in his 1963 and 1969 papers and Mandelbrot in 1979[10] had laid the foundations much earlier. Mandelbrot created the "theory of roughness", and he saw "roughness" in the shapes of mountains, coastlines and river basins; the structures of plants, blood vessels and lungs; the clustering of galaxies. His personal quest was to create some mathematical formula to measure the overall "roughness" of such objects in nature. He partially succeeded and invented the term fractal to describe how simple mathematical

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[7] Macrae, N. 1992. John von Neumann. New York: Pantheon. p. 370.
[8] Von Bertalanffy, L., 1968. General Systems Theory. New York: Braziller.
[9] Gleich, J. 1987. Chaos: making a new science. Penguin.
[10] Lorentz, E.N., 1963. Deterministic nonperiodic flow. J. Atmos. Sci., 20, 130-141; Lorentz, E.N., 1969. Atmospheric Predictability as Revealed by Naturally Occurring Analogues. J. Atmos. Sci., 26, 636–646.

formulae could result in seemingly chaotic results—leading many to see fractals in music, painting, architecture, and stock market prices. Mandelbrot believed that fractals, far from being unnatural, were in many ways more intuitive and natural than the artificially smooth objects of traditional Euclidean geometry.

Chaos theory at its heart is a mathematical description of phenomena which show a range of unpredictable results from similar initial conditions. The Lorentz attractor (usually just called attractor today) describes the variety of patterns which emerge in chaotic phenomena. The success of Lorenz, Mandelbrot and their followers is in describing the chaos of nature or in inducing chaos in systems where too much order has created pathology. Workers in mathematical chaos theory had little success in determining the origins of chaos, in deciphering the "prime language" underlying chaos. This understanding awaited the transformation of chaos theory into complex adaptive system theory.

Since all life is adaptive and chaotic, no algorithms or mathematical models can describe them. Furthermore, the self-organizing tendencies of adaptive systems insure emergent qualities which can't be predicted by algorithms based on the component systems. Emergence is the union of complementary units to create a new whole with different properties not predictable from its component units. Yet we expend immense resources trying to get closer to understanding, prediction and control by applying more of the same medicine which hasn't worked in the past. Sometimes our models do a little better at predicting (say the weather) and our faith in them is restored (though at the price of ignoring all the times the models fail).

> The successful manager or engineer does not depend or trust wholly in any mathematical model or algorithm. He tinkers with the system, modifies it and makes it work and adapts his system to changes from outside. He is creating a whole. He is managing chaos.

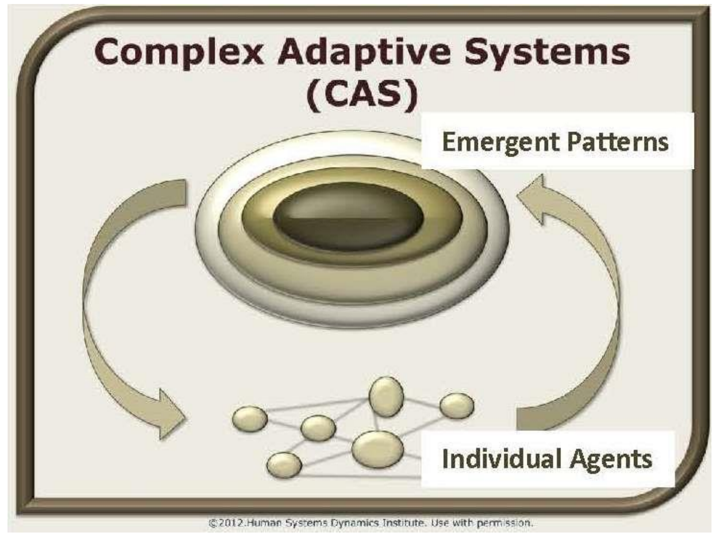
What we too often ignore is that too much order causes pathology. Our hearts, for example, rely on the unpredictable activity of individual heart muscles cells which organize themselves into a regular pattern which keeps blood flowing properly. When the heart cells begin to act less chaotically and with too much order, often a heart attack is imminent. Chaos must be induced to bring back normal functioning as Ditto and his colleagues have shown.[11]Similar phenomena have been shown to occur in brain malfunction. Epileptic seizures show too much order and too little chaos in brain cell firing.[12]

Our human tendency to seek out order in the Universe leads us to look at chaos as an absence of order. We see something missing, but in fact order is the state which is missing something. Chaos is not an

[11] Garfinkel A, Spano ML, Ditto WL, Weiss JN. 1992. Controlling cardiac chaos. Science 257:1230-5.
[12] Sarbadhikari, S. N. and K. Chakrabarty, 2001. Chaos in the brain. Medical Engineering & Physics 23: 445–455.

absence of energy, but energy pushing in lots of different directions. Order eliminates or suppresses all but the desired activities. Chaos theorists looked for order within chaos. They were primarily mathematicians observing data and looking for trends, rather than seeking the cause of chaos in Nature.

Succeeding chaos theory, complex adaptive system (or CAS) theory recognizes that most systems have a capacity for self-organization and adaptation. This conceptual framework recognizes the complexity of systems (ecological, economic, and social) in their hierarchical structures. The interactions and energy flows between hierarchies, systems and subsystems creates self-organization and adaptation in all systems. A complex adaptive system is a system that has a diversity of "agents" (also CAS) which are connected, with certain behaviors and actions which are interdependent and which exhibit adaptation and self-organization.




You are a system made up of multiple competing impulses. One part of you wants to read this article. Another part wants to call up that girl in Entomology class. Another part wants to go outside and pick some berries. Another part is mad at an enemy and wants to find him and punch him. Another part wants to throw away this article and go drink a cool one on the porch.

**These multiple conflicting impulses can be seen as subsystems jockeying to control the larger system—you. All these impulses are useful—when applied at the right time.**

A student could continue to follow the impulse to read this article while his house burns down around him. He could also continue to read this book while a pretty girl flirts with him until she gives up and doesn't become his wife after all. Or he could throw the book away and spend all his time in bars paying attention to the pretty girls who flirt with him. Encouraging the appropriate impulse (adaptive system) is the task of the manager. All resilient systems are chaotic in the sense of having multiple conflicting impulses (or adaptive subsystems) which arise in response to external change.

If you've ever tried to manage a class of American 15 year old males, you know about chaos. They are the embodiment of multiple competing impulses. They want to get outside and ride their motorcycles. They want to ask out that girl in the second row. They want to work hard and get good grades. They want to escape school and never come back. They want to smack that stupid football player.

All these energies (capacity to do work) if focused in one direction, represent potential. The key quality of complex adaptive systems is the management of multiple conflicting impulses. The right impulse must come out at the right time and be suppressed when the time for its expression is not right.

Those seeking to understand food systems have been slow to adopt this perspective even as many fields, such as physics, medicine, ecology and psychology are rapidly embracing it. All agriculturalists have not been so slow, however. Foresters have been a bit quicker due to the widespread influence of forest ecologists in forest management.

Ecosystems are complex, adaptive systems characterized by historical dependency, non-linear dynamics, and multiple basins of attraction.[13] We are part of ecosystems and alter their dynamics through activities that change the atmosphere and climate, land surface, and waters. In the future, we are likely to face different, more variable environments, and there will be greater uncertainty about how ecosystems will respond to the inevitable increases in levels of use.

The successful manager or engineer does not depend or trust wholly in any mathematical model or algorithm. He tinkers with the system, modifies it and makes it work and adapts his system to changes from outside. He is creating a whole. He is managing chaos. He is a complex adaptive system interacting with other complex adaptive systems.

## Eight qualities of ecological resilience

With this background in ecological resilience and complex adaptive systems, we have a foundation for understanding why some local food systems are resilient and others not. Specifically, we can see how local food systems manage to survive in recalcitrant areas which are not congenial to local food.

Many have explored the qualities which make a system resilient. Recently various researchers have begun to assess resilience of highly managed agroecosystems.[14] Stockholm Resilience Centre solidifies how explaining and predicting resilience in such systems requires understanding the complex adaptive systems people interact with.[15] A multitude of frameworks have been developed for these social-ecological systems.[16] However, the complexity of interactions within each social-ecological systems (SES) make each SES unique and render impossible accounting for every factor that conditions resilience now and in the future. Any framework will focus on a few of these factors and none can encompass all.

Seeing the impossibility of predicting interaction of innumerable complex adaptive systems, many researchers have focused on defining the basic qualities which appear in all resilient systems. One of the earliest attempts by resilience pioneers Brian Walker[17] formulated a set of nine necessary qualities for a resilient world: Diversity, Ecological Variability, Modularity, Acknowledging Slow Variables, Tight Feedbacks, Social Capital, Innovation, Overlap in Governance, and Ecosystem Services.

Carpenter et al.[18] clarified the distinction between the specific "resilience of what to what" and general resilience which confers the ability cope with any disturbance. They went on to posit nine slightly

[13] Levin, S.A., 1998. Ecosystems and the biosphere as complex adaptive systems. Ecosystems, 1:431–436.

[14] The most prominent frameworks for assessing and improving ecological resilience are discussed in more detail in Chapter 10.

[15] Levin, S., Xepapadeas, A., Crépin, A.-S., Norberg, J., de Zeeuw, A., Folke, C., Hughes, T., Arrow, K., Barrett, S., Daily, G., Ehrlich, P., Kautsky, N., Mäler, K.-G, Polasky, S, Troell, M., Vincent, J.R., Walker, B., 2013. Social-ecological systems as complex adaptive systems: modeling and policy implications. Environment and Development Economics, 18 (2).

[16] Binder, C. R., J. Hinkel, P. W. G. Bots, and C. Pahl-Wostl. 2013. Comparison of frameworks for analyzing social-ecological systems. Ecology and Society 18(4): 26. http://dx.doi.org/10.5751/ES-05551-180426

[17] Walker, B. and D. Salt, 2006. Resilience Thinking. Island Press.

[18] Carpenter, Stephen R., Kenneth J. Arrow, Scott Barrett, Reinette Biggs, William A. Brock, Anne-Sophie Crépin, Gustav Engström, Carl Folke, Terry P. Hughes, Nils Kautsky, Chuan-Zhong Li, Geoffrey McCarney, Kyle Meng, Karl-Göran Mäler, Stephen Polasky, Marten Scheffer, Jason Shogren, Thomas Sterner, Jeffrey R. Vincent, Brian Walker, Anastasios Xepapadeas and Aart de Zeeuw, 2012. General Resilience to Cope with Extreme Events. Sustainability, 4:3248-3259; doi:10.3390/su4123248

different qualities which enable general resilience: diversity, modularity, openness, reserves, feedbacks, nestedness, monitoring, leadership, and trust.

The Frankenberger et al.[19] conceptual framework for community resilience is an influential treatment of resilience in international community development. This framework posits seven central "community social dimensions." These are preparedness, responsiveness/flexibility, learning and innovation, self-organization, diversity, inclusion and aspirations.

Rockefeller Foundation [20] has developed a City Resilience Framework which posits seven qualities of resilient systems: reflective, robust, redundant, flexible, resourceful, inclusive and integrated.

The Stockholm Resilience Center (SRC)[21] developed a set of "seven principles that are considered crucial for building resilience in social-ecological systems": maintain diversity and redundancy, manage connectivity, manage slow variables and feedbacks, foster complex adaptive systems, encourage learning, broaden participation, and promote polycentric governance.

For agroecosystems, the most relevant framework to date is Cabell and Oelofse[22] which details thirteen categories of indicators shown to be associated with resilience: socially self-organized, ecologically self-regulated, appropriately connected, functional and response diversity, optimally redundant, reflective and shared learning, spatial and temporal heterogeneity, exposed to disturbance, coupled with local natural capital, globally autonomous and locally interdependent, honors legacy, build human capital and reasonably profitable.

As we applied all these frameworks to resilient Southern farms and communities, we realized that systems which last often must balance seemingly contradictory impulses. We are all born selfish. We enter the world crying and demanding the food and physical attention we need. However, soon our altruistic side shows as we naturally want to help other people. This combination of contradictory impulses is present in all living systems.

In the context of the frameworks discussed above, below we preview the eight sets of contradictory impulses necessary to enable ecological resilience, the ability to withstand disturbance while maintaining basic system functions and services.

**Local self-organization**. One quality common to several of these frameworks, self-organization, refers to the emergence of new entities from those existing together in a particular locality. Frankenberger et al. and Cabell and Oelofse have a strong focus on the importance of the locally self-organized quality in resilient systems. Cabell and Oelofse use the term socially self-organized and specifically cite the example of local food systems in the US. They make a distinction echoed in many other frameworks, that locally self-organized networks can be more responsive and adaptable to changing conditions. Top-down initiatives fail if the timing is wrong due to inadequate knowledge of local conditions, if drivers of the local systems are misunderstood, or if there is no buy-in from local stakeholders, participants, and communities.

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[19] Frankenberger, T., Mueller M., Spangler T., and Alexander S. October 2013. Community Resilience: Conceptual Framework and Measurement Feed the Future Learning Agenda. Rockville, MD: Westat.
[20] https://www.rockefellerfoundation.org/report/city-resilience-framework/
[21] Biggs, R., et al., 2015. Principles for Building Resilience in Social-Ecological Systems. Resilience Alliance and Cambridge University Press.
[22] Cabell, J. F., and M. Oelofse. 2012. An indicator framework for assessing agroecosystem resilience. Ecology and Society 17(1): 18. http://dx.doi.org/10.5751/ES-04666-170118.

Other frameworks are less specific about the need for local self-organization, but imply its importance in the quality labeled inclusiveness (Rockefeller and Frankenberger et al.), overlap in governance (Walker and Salt), nestedness (Carpenter et al.) and polycentric governance (SRC). These four frameworks all focus on the need for governance above the local level to be focused on resilience.

Certainly, every resilient system can contribute to the resilience of subsystems of which it is composed. Further, all ecosystems are nested since every system is composed of systems. However, particular subsystems may be sacrificed if such enhances resilience at a higher scale. Furthermore, since what is local is relative to scale (local for a planet is far different from local for a Rhizobium), regional, national and world governance are examined at their own scales. Resilience then implies local self-organization at all scales.

Superficially, this factor may be counterintuitive. A farmer may justifiably ask: "How can I just let go and let things organize themselves? How can I focus locally when the forces which control the world are beyond my local level?"

Twenty years ago, Southern SARE was instrumental in providing answers to those questions in a landmark study analyzing the constraints and opportunities most crucial to development of sustainable agricultural systems in the South. This study was published in 1995 as "Southern Futures: Opportunities for Sustainable Agricultural Systems" and referred to as the State of the South (SOS).

SOS (LS92-050)[23] integrated agroecoregion focus groups and a regional survey with secondary databases. The study concluded that locally organized processing and marketing systems were crucial to development of sustainable agricultural systems. The study showed that resilient examples of such systems have more sales to local markets, use more local resources, establish close relationships between producer and consumer, and share resources such as equipment. Farmers and consumers in these systems organize into grassroots networks and institutions such as processing and marketing cooperatives, farmer's markets, and community-supported agriculture (CSA) marketing systems.

Since that study, encouraging locally-owned processing and marketing systems has become a national focus in the United States. Several state and federal programs have been implemented to address this constraint (e.g., Value-Added Producer Grants, Farmers Market Promotion Program, Local Foods Promotion Program, Kentucky Agricultural Development Board, Know Your Farmer, Know Your Food, Compass and many other national, regional and local programs). USDA's Economic Research Service has progressed from dismissing as trivial the likely impact of local foods in a white paper in 2000[24] to trumpeting loudly the importance of local foods in 2010.[25] When a conservative Arkansas Congressmen says "The future of food is local"[26] and WalMart pledges to increase local food to 15% of its total food sales[27], we can rest assured that interventions will continue to increase the locally self-organized quality in the United States.

[23] Worstell, J., 1995. Southern Futures: Opportunities for Sustainable Agricultural Systems. Almyra, AR: Delta Land & Community. Also available at: http://mysare.sare.org/mySARE/assocfiles/483Southern%20Futures.pdf
[24] ERS. 2000. Food and Agricultural Policy, Washington, D.C.: USDA. Pp. 16-35.
[25] ERS, 2010. Local Food Systems: Concepts, Impacts, Issues. Washington, D.C.: USDA.
[26] Crawford, R., 2013. U.S. Rep. Rick Crawford speaking in DC and Jonesboro, AR.
[27] Wal-Mart, 2013. http://www.arkansasonline.com/news/2013/jun/04/retailer-stock-fresher-produce-20130604/

Some regions of the US have not seen the vast rise in local food systems experienced by others. One prominent 2015 index[28] puts only two of the Southern states (South Carolina and Virginia) in the top half of all US States in presence of local food systems. North Carolina is 28th, Kentucky 29th and the other nine Southern states are ranked in the lowest 11 states. All the lowest ranking Southern states are decreasing yearly relative to the rest of the nation, according to this index.

The top four Southern states are very similar in demography and geography to Tennessee, Mississippi and Arkansas which rank near the bottom of all US States. Even in these states where locally self-organized food systems are rare, some do exist. Local food systems which are resilient in such areas have been able to overcome barriers and disturbances presumably not seen in areas where self-organized local food systems are plentiful.

We decided to examine resilient local food systems in such recalcitrant areas to identify the qualities beyond local self-organization necessary for achieving resilient agricultural systems. Nine case studies of resilient local food systems in Tennessee, Arkansas and Mississippi were developed and analyzed in the context of the frameworks noted above--resulting in the emergence of seven more qualities common to all these resilient local food systems. All these case studies are available online.[29]

**Modular connectivity.** Closely related to the locally self-organized quality is a quality which integrates two seemingly contradictory factors: modularity and connectivity. We also refer to this quality as "networked, but independent." Resilient systems are sensitive and responsive to feedback, while maintaining independence. Modular or independent sub-systems are insulated. Damage or failure of even a key sub-system has low probability of propagating failure throughout the system. Yet each component system can detect and respond to changes throughout the system, thus being able to cope with change. Resilient connectivity has a few strong connections and many weak connections.

Each of the eight resilient systems in the case studies was composed of a few tight-knit actors with a wide range of connections to marketing, policy, input supply and other systems. In the language of social capital, resilient systems have high levels of bonding, bridging and linking social capital.

Nearly all prominent resilience frameworks recognize the importance of connectivity and modularilty. Some make social capital a separate category. We see social capital as describing a type of connectivity which occurs in all systems, not just human systems. Bonding social capital contributes to the strong modularity of a system, while bridging and linking social capital provide connectivity outside the immediate group. Carpenter et al. have a strong focus on modular connectivity. However, they split this quality into several separate areas: modularity, managing feedback, monitoring, openness, and development of trust.

Cabell and Oelofse call the quality "appropriately connected." Frankenberger et al. see the vital importance of social capital, but discuss other aspects of connectivity in less detail and do not discuss modularity. Stockholm Resilience Center focuses on managing connectivity and feedbacks, but with less evident emphasis on modularity than other frameworks. While extolling connectivity, every system encounters situations where high connectivity leads to low resilience to disturbance. If the system is not modular or independent, it can't be resilient when disturbance floods though systems.

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[28] http://www.strollingoftheheifers.com/locavoreindex/

[29] https://meadowcreekvalley.wordpress.com/projects/land/roots-of-resilience-the-book/.

Rockefeller uses slightly different terminology. Instead of connectivity, they refer to resilient systems as integrated (where exchange of information between systems enables them to function collectively and respond rapidly through shorter feedback loops). Instead of modularity, they use the term robust. Systems are robust if they actively avoid over-reliance on a single physical infrastructure, cascading failure and design thresholds that might lead to catastrophic collapse if exceeded are actively avoided. The opposing tendencies united in this quality are illustrated by two questions: Do you need to be independent? Do you also need to be connected with others?

We all want to be independent, but we also have a deep need for connection with other people. All resilient systems we looked at had a strong local network focused on collaboration, cooperation to achieve goals of sustainability while linked to other systems. Community groups dedicated to collaborative learning have been instrumental in increasing adoption of a variety of conservation measures by farmers. Resilient managers also have extensive connections outside their local group to bring in new ideas, new markets. This connectivity is tempered with modularity, the ability of systems to survive when related systems fail. Resilient systems are not so tightly connected that they fail when other systems connected to them fail.

**Ecological integration or working with nature.** This factor may also seem counterintuitive or even wishful thinking, a pie in the sky. Many productive and enduring farmers ask: "How can I work with nature when nature seems to continually be destroying my best efforts?"

As a result of trying to control all the aspects of natural systems which seem inimical to farmers, agroecosystems are often are not well integrated into local ecological systems. More resilient agricultural systems, however, obtain services from their surrounding ecosystem. Integrated pest management uses natural predators and parasites to assist in control of pests. Management Intensive Grazing mimics natural processes to increase productivity of grasslands and reduce parasites on grazing animals. Resilient farms maintain plant cover and incorporate more perennials, use ecosystem engineers such as soil fauna, and align production with local ecological parameters.

Lack of adaptation to local ecological conditions inevitably decreases resilience and even leads to the destruction of societies. Examples are legion. Inuit methods enabled them to thrive as Norwegians died out while clinging to an agricultural system not suited to a changing climate.[30] Hundreds of dead cities reflect a similar failure in the mid and far east.[31]

Of all the resilience frameworks, Cabell and Oelofse are most explicit in recognizing the value of ecological integration when they state that the more intact and robust the regulating ecosystem services are, the more resilient the agroecosystem. They further suggest that more resilient systems are more capable of self-regulation.

Rockefeller's discussion of integration and the importance placed on diversity by all other frameworks make this quality of ecological integration implicit in all the frameworks. Our analysis of resilient local food systems indicates that the quality should be explicitly measured and induced.

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[30] (Diamond,J. 2006. Collapse: How Societies Choose to Fail or Succeed. Viking.
[31] Lowdermilk, W.C., 1953. Conquest of the land through seven thousand years. USDA/NRCS. http://www.nrcs.usda.gov/Internet/FSE_DOCUMENTS/stelprdb1043789.pdf

**Complementary diversity.** Echoing the ecosystems in which they are integrated, resilient systems are highly diverse, but the diversity is controlled. It is complementary in function, use of inputs, and generation of outputs. All ecosystems are founded on species consuming and being consumed by each other. That is, species complement each other by providing outputs which, though wastes to that species, are resources to other species.
A variety of crops, many markets, many sources of inputs, and spatial heterogeneity all illustrate diversity in resilient local food systems. Such diverse components give other components what they need, feed each other, producing not waste, but resources for other components. Heterogeneity of features within the landscape and on the farm along with diversity of inputs, outputs, income sources, markets, and pest control methods all reflect this diversity in resilient systems.

Though increased diversity is associated with resilience, increasing diversity can lead to a decline in resilience and long-term reduction in diversity. Prime examples are the introduction of invasive species such as kudzu in the U.S. Southern States, rabbits in Australia and a host of other examples (ref). Where diversity is not complementary, it decreases resilience. Extreme levels of diversity characterize resilient systems, but increasing diversity, if it isn't a complementary diversity, can destroy diversity and lead to a decline in system resilience. A farmer with too many enterprises cannot give enough attention to each and his whole system may collapse. Every species or system must both give and take resources. Species which only take resources (such as farm which mine the soil instead of replacing nutrients) die out because they undermine the system which supplies those resources.

Diversity is extolled by nearly all resilience frameworks. Some frameworks (e.g., Carpenter et al., SRC and Frankenberger et al.) do not address the need for diversity to be complementary or that diversity can undermine resilience. Cabell and Oelofse, in contrast, make this distinction explicit. They also include, as a separate quality, spatial and temporal heterogeneity which is lack of uniformity across the landscape and through time. In resilient local food systems, this seems to be an indicator of diversity, not a separate quality from diversity.

Though Rockefeller fails to explicitly mention the quality of diversity in their 2014 index, in 2015, their website included diversity as a characteristics of all resilient systems.

**Responsive redundancy/back-ups**. Diversity may seem to be the opposite of ecological redundancy, but in fact it can contribute to redundancy. Redundancy concerns questions such as: "Who will take over my farm or business when you retire? Why is it so hard for young people to begin farming? When does saving for a rainy day or stockpiling supplies and equipment become hoarding? How can I be efficient when I have to have all these redundant systems?

Redundancy is seen as crucial in all resilience frameworks, though Frankenberger et al. does not explicitly use the term. Cabell and Oelofse use the term optimally redundant. This highlights a crucial qualification since redundancy inevitably increases inefficiency of the system--making perhaps the most glaring contrast and intellectual hurdle for profit-oriented agricultural systems. Resilience can be low even if profit is through the roof. Sacrificing the future for immediate profit is the sure root to non-resilience. Redundancy must walk the tightrope of efficiency--being efficient enough to survive, but not by scrimping on backups.

Reserves, as the term is used by Carpenter et al., seems to overlap both the redundancy and building physical infrastructure qualities of resilient local food systems.

Resilient systems have back-ups and replenish their components. Redundancy means several of each component are present and they are replaced when lost. Resilient systems reproduce themselves and have overlapping subsystems which perform the same functions in multiple different ways. Redundancy which promotes resilience is responsive to needs of the system. Overpopulation does not occur. The resilient system has mechanisms to control excessive fecundity. Skills, abilities, functions are also reproduced and passed on to the next generation. Diversity is closely related to redundancy since maintaining diversity limits dominance of any particular component. Planting multiple varieties of crops rather than one, keeping equipment for various crops, getting nutrients from multiple sources, capturing water from multiple sources all are examples of redundancy contributing to resilience

Lack of redundancy at a national scale (farmers aging and lack of young farmers) can be countered at a local scale when managers bring in young people and their fresh ideas to increase redundancy on their farms and in their businesses. Investment in infrastructure and institutions for the education of children and adults and support for social events in farming communities all promote redundancy. At the scale of state and national policy, programs such as USDA's Beginning Farmer Rancher Development Program are interventions which increase the redundancy quality of resilience.

**Increasing Physical Infrastructure**. Closely related to redundancy is increasing the physical infrastructure in a system. Various resilient farmers ask: "How can I build the resources I need for my farm and my system to survive and prosper? How can I build infrastructure when I have none? What physical infrastructure is crucial to resilience?" At a larger scale, examination of this quality addresses why the rich get richer and the poor get poorer.

The quality of Increasing physical infrastructure is reflected in increasing productive physical physical infrastructure and natural capital, such as structures which reduce soil erosion, increasing organic matter in soils, water catchment, building levels of soil organisms which fix nitrogen and make nutrients more available (such as vesicular arbuscular mycorrhizae), on-farm waste processing, and on-farm storage and processing. All these are physical infrastructure which, if increasing lead to increased resilience and, If decreasing, lead to less resilience in local food systems.

At a higher scale, state policies to preserve farmland, federal loan programs to increase on-farm storage, and state and federal programs to increase farmer owned value-added processing and marketing all increase resilience by maintaining and increasing crucial physical physical infrastructure.

Building physical physical infrastructure also requires local self-organizing, and provides a downstream measure of the local self-organizing quality.

Rockefeller is most explicit about the need for physical physical infrastructure. They cite the importance of well-conceived, constructed and managed physical physical infrastructure, which enable a system to withstand the impacts of disturbance without significant damage or loss of function.

Cabell and Oelofse emphasize that resilient systems are coupled with local natural capital—the slow variables such as soil organic matter, hydrological cycles, and biodiversity. SRC also notes the importance of managing slow variables, though without emphasis on building up such physical infrastructure, perhaps because their focus is not primarily agroecosystems.

Frankenberger et al. highlight community physical infrastructure, which are resources that enable communities to meet the basic needs of their members and reduce vulnerability to shocks.

Frankenberger et al. propose two other qualities which are not explicitly stated in other conceptualizations, but are related to increasing physical infrastructure: preparedness and aspiration. Preparedness refers to the community resources needed to cope with disturbance. Aspirations are the underlying personal qualities which make people make investments needed to cope with disturbance.

The other frameworks examined here are not explicit about the necessity of building infrastructure or physical physical infrastructure for resilient systems, though the quality seems to be assumed in such terms as reserves (e.g., by Carpenter et al.) which contribute to recovery from disturbance. Reserves cannot be created without the productive infrastructure needed to create them. Reserves also reflect the presence of redundancy (or back-ups) as shown above. The increasing physical infrastructure quality focuses on the means of production, while responsive redundancy focuses on the ability to reproduce and maintain the system.

The resilient manager recognizes the stage of the adaptive cycle their system is in to determine which infrastructure needs to be increased first and most. Maintenance of infrastructure is crucial, whether the infrastructure component is soil, water supply, or machines. Soil organic matter is a key infrastructural component for the farm and for the global climate.

The most important infrastructure for any farmer is himself and his workers. However, one aspect of these workers comprises a distinct quality: applying skills flexibly and innovating conservatively.

**Conservative innovation.** If innovation is the foundation for all progress, then why are so many ideas worthless and how does a manager choose among them? How can a manager determine which new ideas best fit my system and which to spurn?

In resilient systems, innovation only lasts if it conserves the tried and true from the past. Adaptation, flexibility and innovation elucidate how agricultural innovation is a co-evolutionary process. Lack of innovation in some systems leads to rigidity traps which limit innovation if management closes the system to new ideas and practices.

Resilient systems are open to new ideas while retaining ideas which work from the past. That is, they have a conservative innovativeness and flexibility. As Holling (2001, pp. 398-99) noted, resilient systems are both creative and conservative. The most resilient farmer is usually not the first adopter of new technology, rather, he employs the technology when it is proven, but far more quickly than most. Since resilience requires the ability to come up with uniquely appropriate responses in diverse situations, the system needs a variety of approaches. Ecologically resilient systems stress multiple, overlapping strategies rather than silver bullets. Overcoming a disturbance often requires innovation.

Innovation is a necessary quality of resilient systems in nearly all frameworks. Carpenter et al. discuss it under their term openness; Rockefeller under flexible, resourceful and reflective; Cabell and Oelofse discuss innovation under building human capital and reflected and shared learning; SRC under encourage learning; Frankenberger et al. under responsiveness/flexibility and learning and innovation.

Many frameworks, however, are not as explicit about the dangers of innovation which does not, as Cabell and Oelofse put it, honor legacy. Legacy is the memory component of the SES. Frankenberger et al. refers to this quality as strong community memory of traditions, practices, past disasters, and changing conditions supporting communities' abilities to draw on experience to prepare for and respond to similar challenges. As with many qualities of resilience a duality is present: the system must innovate, but it must also preserve tried and true systems.

**Periodic transformation.** Many farmers and other agricultural and food system managers say: "Since I built this system, who better than me to run it? Why should I give up control when I own this farm, this business? Things are running along smoothly; why do I need to change? I want to minimize the effect of disruptions; why should I embrace disruption and incorporate it in my system?"

Innovation within a system is transformative on a smaller scale and is a quality all recognize as necessary to resilience. Most frameworks don't make the leap to recognizing that sometimes the innovation required may be so extensive as to transform the entire system. This limited embrace of transformation is illustrated by Rockefeller's emphasis on reflective systems which notes that resilient systems have mechanisms to continuously evolve, but does not go so far as to say they are periodically totally transformed.

Ecological resilience research has revealed that there are no climax communities. What appears to be a balance of nature is an epiphenomena. All systems will be replaced by systems which flourish on the residue of the previous system. In resilient systems, death is renewal. Creative destruction always is the result of maturation of a resilient system. Innovation to adapt to disturbance is always transformative at some scale. Transformative innovation create disturbances which transform systems. Dissolution of the old as a precursor to a more powerful system.

Management is part of any ecosystem. No system is without man's influence, so we do not have the option of withdrawing from Nature in order to save it. We must facilitate transformation consistent with all eight factors of resilience.

Resilience, whether psychological or ecological, is based on growth which embraces change. Stressing returning to normal undermines resilience. Innumerable societies have been destroyed by managing to minimize disruption. Focusing on sustainability of the present system can decrease resilience in the face of unexpected disturbance.

**Combining the eight qualities into an overall index of sustainability/resilience.** Using the methods described in the Appendix, we obtained data for every county in the 13 Southern States on all these qualities for which county level indicators are available. The next eight chapters provide this data for each quality. We united the data from all these qualities in an overall sustainability/resilience index (SRI) which provides estimates of sustainability/resilience for each county in the South.

County-level SRI scores are summarized in presented in Table 1 and summarized in the adjoining chart. Virginia counties had higher scores than any other Southern State. 68% of Virginia counties scored in the top quartile of all Southern counties. North Carolina was second with 53% of counties in the top quartile. Kentucky was third with 46.7%. However, Kentucky had the lowest number of counties in the lowest quartile of all Southern States (2.5%).

| States ranked by % of counties in highest quartile across South | | |
|---|---|---|
| Rank | State | % |
| 1 | Virginia | 68.3 |
| 2 | North Carolina | 50.3 |
| 3 | Kentucky | 46.7 |
| 4 | South Carolina | 32.6 |
| 5 | Florida | 31.3 |
| 6 | Louisiana | 27.4 |
| 7 | Tennessee | 17.9 |
| 8 | Arkansas | 17.4 |
| 9 | Georgia | 14.5 |
| 10 | Oklahoma | 13.0 |
| 11 | Texas | 11.8 |
| 12 | Alabama | 3.0 |
| 13 | Mississippi | 2.4 |

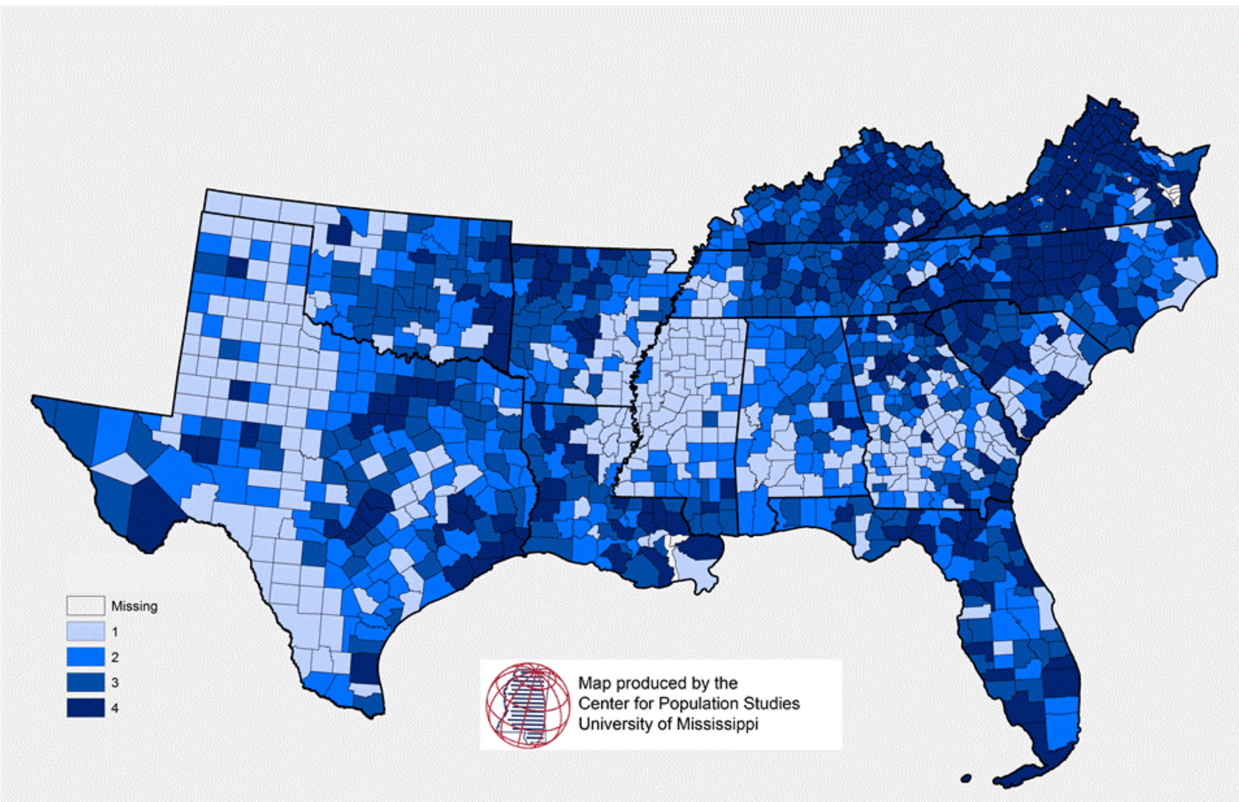
Mississippi, on the other hand, had 68.3% of counties in the lowest quartile, for the lowest ranking of all Southern States. Only 2.4% of Mississippi Counties ranked in the highest quartile of Southern counties. Alabama was second lowest overall with 3% in the highest quartile.

The data reveal a fascinating set of patterns. Mississippi is extremely bottom heavy with number of counties in each quartile growing exponentially as the scores go lower. The highest number of counties per quartile for Alabama, however, was the second lowest quartile.

Other states, though having high numbers of counties in the lowest category, had flatter distributions, spread over all quartiles. Georgia had the second highest number of counties in the lowest quartile (40.9%), but still managed to get 14.5% of counties into the highest quartile.

Since simple means lose much of this wealth of data, we have not presented means for the total SRI scores. Number of counties ranking in the top quartile across the South seems a better measure of how each state is moving toward sustainability/resilience. The percentages and ranking of each Southern State are shown in the adjacent box.

**Local Agrifood Resiliency: Summation Across All Indicators** (Quartile Ranks)




Based on summated and standardized scores across 11 indicators. A higher quartile ranking indicates a higher level of resiliency on this measure. State of the South data sources: 2012 Census of Agriculture, 2013 Food Atlas, and 2014 review of state policies and regulations; extra calculations by the University of Mississippi Center for Population Studies. Analysis based on 1304 counties.

Total SRI scores show Southern states falling into five groups based on these scores. Virginia stands out above other states. North Carolina and Kentucky make up the second tier. South Carolina, Florida and Louisiana have similar percentages to comprise a third tier (32.6 to 27.4). Tennessee, Arkansas, Georgia, Oklahoma and Texas comprise a fourth tier with scores from near 12 to 17.9. Alabama and Mississippi are clearly at the bottom on this measure of sustainability/resilience at the county level.

**Summary.** The above gave you a taste of the eight roots of resilience. The purpose of this book is to help you establish these eight foundations in the system you manage. To do so, we include in every chapter methods for self-assessment of resilience in your systems.

We don't pretend we have the final answers, we just hope to help define the questions which will lead to particular local answers for your system. Below we propose a set of such questions at the scale of the farm, but they are seem applicable to all scales from soil to food system to the planet. So substitute the system you are managing for "farm" in the following.

1. How is your farm independent yet tightly connected to other farms, markets and government policy systems?
2. How is your farm welcoming diversity of species and enterprises in ways complementary to its existing components?
3. How is your farm establishing back-ups and redundancy?
4. Are you insuring your farm is as locally-oriented as possible? How are you helping your local systems to self-organize to increase resilience?
5. What physical infrastructure are you building on your farm? How do they contribute to your farms resilience?
6. Is your farm increasingly working with nature, achieving ecological integration?
7. How do you insure innovation is regularly occurring on your farm in a way which conserves the tried and true methods which built it?
8. Is your farm embracing the chaos of disturbance and transformation?

Whether your system is a household garden or a thousand acre farm, this book will help you develop systems which are more resistant to disturbance and can transform into systems with even more resilience.

We begin with the foundation of all resilient systems: local self-organization.