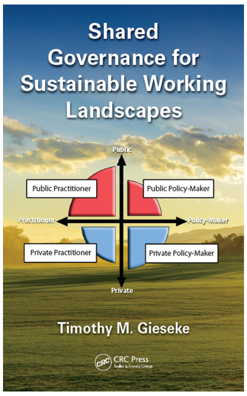

Shared Governance for Sustainable Working Landscapes

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An enduring wicked problem

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section one

An enduring wicked problem

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chapter two

An enduring wicked problem

Finding the path toward agricultural landscape sustainability remains a significant challenge in the early twenty-first century. This challenge of reaping economic rewards while sustaining the landscape has long been with humankind. Made famous by Garrett Hardin's (1968) *Tragedy of the Commons* essay and noted nearly 2500 years earlier in the writings of Aristotle, society's answer to landscape sustainability remains unresolved (Waldron, 2004).

2.1 A wicked problem

Achieving landscape sustainability is a complex endeavor consisting of social, economic, and ecological components. The agricultural landscape has functional qualities at many scales and scopes. From the incalculable biodiversity interworking of *a teaspoon of soil* to the water purification processes within a great river basin, each is interrelated and undefinable. Within these contexts, there are many diverse stakeholders having common and conflicting objectives. Organizations, numbering in the thousands, are involved in all aspects of landscape use and sustainability. By many accounts, achieving agricultural landscape sustainability is a *wicked problem* (Balint, 2011; Bruggemann et al., 2012; Davies, 2015; Howes and Wyrwoll, 2012; Jones, 2011; Hearnshaw et al., 2011; Hunt and Thornsbury, 2014; Ostrom, 2007; Sørensen and Torfing, 2012; Scholz and Stiftel, 2005).

The term *wicked* in this context is used, not in the sense of evil, but rather as an issue highly resistant to resolution (Commonwealth of Australia, 2007). Since wicked problems are not always clear in their solution or in the steps to be taken, it is difficult to know whether the desired outcomes are being produced or even ultimately achieved. Wicked problems have become commonplace as these types of problems include nearly all social issues involving human health, education, transportation, and the environment. Wicked problems are a product of the increasing complexity and uncertainty of the physical world and social issues (Meuleman, 2013).

In contrast, *tame* problems are those that scientists and engineers usually work on (Rittel and Webber, 1973). For example, landing a human on the moon, sequencing DNA, and building a dam are tame problems. For each, the task is relatively clear; specific steps can be made and then

Knowledge \ Values	Consensus	Disagreement
Consensus	**Technical**	**Political**
Disagreement	**Scientific**	**Wicked**

Figure 2.1 The types and sources of problems are related to the consensus and disagreement on the knowledge and values associated with an issue. If there is consensus on both knowledge and values the problem to be resolved is technical in nature. Scientific and political problems are based on different combinations of consensus and disagreement on the values and knowledge of an issue. The source of a wicked problem is disagreement on both values and knowledge of an issue. (From Meuleman, L., *Transgovernance: Advancing Sustainability Governance,* Springer, Heidelberg, 2013.)

replicated to achieve the outcome again. Tame problems, although often complicated, are relatively straightforward as to whether or not the problems have been solved.

Generally, the source of wicked problems is rooted in the lack of consensus as it relates to the values and knowledge of an issue (Meuleman, 2013). Figure 2.1 describes the type of issue to be addressed when there are various combinations of consensus and disagreement on values and/or knowledge. When consensus occurs on values and knowledge, the issues to be resolved are technical. When consensus occurs on values, but not on knowledge, the issues to be resolved are scientific. When consensus occurs on knowledge, but not on values, the issue to be resolved is political. All of these are tame by nature. When there is disagreement on values and knowledge, this issue is wicked.

Wicked problems arise from the interaction of multiple stakeholders with incomplete knowledge and conflicting preferences for the issue at hand. Wicked problem complexity is twofold: complexity of the issue or system and the differing preferences of stakeholders. This twofold complexity renders wicked problems irreducible (Hearnshaw et al., 2011). Socioecological systems such as agricultural landscape sustainability are wicked issues.

2.1.1 Sources of wicked (landscape sustainability) problems

The source of wicked problems cannot be found by traditional problem-solving tactics (Rittel and Webber, 1973). Pure study amounts to procrastination, because little can be learned about a wicked problem by objective data gathering and analysis. Wicked problems demand an opportunity-driven approach: they require making decisions, doing experiments, launching pilot programs, and testing prototypes (Christensen, 2009).

To identify specific problems embedded in socioecological systems, Ostrom (2007) created a diagnostic framework consisting of the system attributes. By focusing on the attributes of (1) the resource system, (2) the resource outputs, (3) the users of the system, and (4) the governance of the system, it gave insights into how the attributes may affect or be affected by socioeconomic, political, and ecological settings in which they are embedded. For example, the issues related to the sustainability of a pasture (resource system) could be diagnosed by measuring the quantity of fodder it produced (resource output) and determining the number and extent of cattle grazing (users) based on the formal and informal rules (governance) of use. Within this framework, Ostrom was able to postulate how changes in one attribute may affect the socioecological system overall.

Jones (2011), a colleague of Elinor Ostrom and researcher of complex social problems, identified three sources of wicked, complex problems. First, the capacities to tackle complex problems are often distributed across a range of stakeholders. Second, complex problems are difficult to predict. And third, complex problems involve conflicting goals. The combination of these sources causes wicked problems to manifest themselves in different ways at different levels. Decision makers at one level perceive solutions differently than those at other levels. The result may be many divergent but equally plausible interpretations of the issue.

Three sources of the wicked problem associated with agriculture landscape sustainability were identified by analyzing 11 case studies. The sources originated within the complexity of the physical environment and social institutions. The following three sources were identified:

1. The varied scope and scale of natural capital outputs and outcomes
2. A growing number of disparate stakeholder values and accounting systems
3. Conflicting governance styles of stakeholder organizations

Individually, each of these problems present challenges to accounting for and valuing the benefits derived from agriculture landscapes. When combined, the complexity of the problem significantly increases. The varied landscape outputs consist of crops, livestock, timber, water, carbon, habitat, and many other benefits. These are produced daily, seasonally, yearly, and decadal, and are sought by numerous stakeholders with different values and intentions. These stakeholders represent hundreds of organizations with differing and often conflicting governance styles. The interrelationship of these three principle problems compounds the complexity of sustaining agricultural landscapes and creates an enduring wicked problem.

2.1.1.1 Varied scope and scale of natural capital outputs and outcomes

Natural capital is one of five generally accepted economic capitals identified along with financial, physical, human, and social. Natural capital, like other economic capitals, refers to "factors of production" that are used to create goods and services, but are not themselves directly consumed. Natural capital is the stock of natural ecosystems that yields a flow of valuable ecosystem goods and services. Ecosystem goods are defined as the tangible consumable goods such as grains, fiber, and water that are produced from the landscape. Ecosystem services are the less tangible processes of the landscape that purify water, pollinate crops, and support wildlife (Daily, 1997).

The scope and scale of agriculture landscape outputs vary greatly. The output can be a specific good, such as a crop at the field scale or water at watershed scale. It may be a specific service, such as pollination, that supports a regional ecosystem or a service, such as carbon sequestration, that affects the atmosphere at the global scale. Despite the great variations in scope and scale, these natural capital components are related ecologically and often related economically. Because of this interdependency, the need to measure, account for, and incorporate these varied values into the economic system is becoming a necessity.

The first-order complexity of the physical nature of agriculture sustainability is compounded by various sectors of agriculture, forestry, fisheries, industries, corporations, governments, NGOs, finance, consumers, and citizens, with each having unique perspectives and demands from the landscape.

2.1.1.2 Growing number of disparate stakeholder values

Prior to the 1970s, agriculture stakeholders in the United States represented local, state, and federal agencies, land grant universities, land owners, farmers, agribusiness retailers, and food processors. Since the 1970s, a growing awareness in the environment and the value of natural capital has greatly expanded the number of stakeholders interested in the agriculture landscape. Stakeholders now include groups associated with bio-energy, environmental advocacy, animal welfare, consumers, corporations, trade groups, private research, and food retail (Sampson et al. 2013).

In addition to stakeholder groups, individual citizens and consumers are demanding more transparency from food processors as it relates to food ingredients and the methods used to grow, process, and transport foods. Corporations, in turn, are applying procurement criteria to suppliers and growers to assess the sustainability of products (The Sustainability Consortium, 2015).

This second-order level of complexity is further compounded by the stakeholders' unique organizational *governance style*. Governance styles can be defined as the processes of decision making and implementation, including the manner in which the organizations relate to each other (Kersbergen and Waarden, 2004).

2.1.1.3 Conflicting governance styles

Governance is an awkward concept as it has different meanings for different individuals and organizations and is applied in various ways (Ho et al., 2014). Governance is a broader term than government, as it is a fundamental component of political, business, social, and government organizations. In its broadest sense, it refers to the various ways through which society is coordinated. Therefore, it is possible to have governance without government or government can be seen as just one of the institutions involved in governance (Rhodes, 1996).

Governance relates to decisions that define expectations, grant power, and verify performance. Governance is also the process of how organizations acquire knowledge and apply strategies (Nickerson and Zenger, 2004). Simply put, governance is how an organization "gets things done" (Meuleman, 2008).

Organizations rely on three governance styles (Thompson, 1991):

1. Hierarchy: a conformist top-down framework with emphasis placed on seniority. Militaries, schools, governments, and churches are often associated with a hierarchy model.
2. Market: an incentive-based top-down framework with emphasis placed on innovation and profit incentives. Corporations are often associated with a market model.
3. Network: a nonhierarchical framework with emphasis placed on purpose and trust. NGOs are often associated with a network model.

Figure 2.2 illustrates each of these governance styles in a schematic form. Hierarchy governance promotes conformity and subordinate accountability. Market governance relies on top-down control, but promotes innovation and profiteering over conformity. Network governance is formed around multiple relationships in both horizontal and vertical manners.

Conflicts arise from the sets of values each of these governance styles contain. Hierarchy governance values are based on the expectation that there should be a *subordinate* to the hierarchy and it relies on regulations and control instruments to meet goals. Market-based governance values a *customer* perspective and relies on competition and innovation to

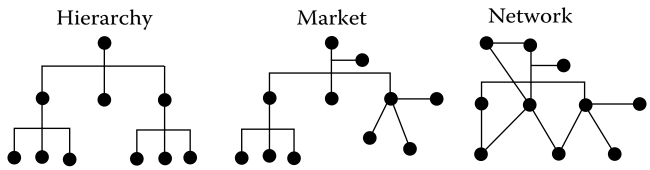

Figure 2.2 Organization governance is based on one of three typical governance styles. Hierarchy is top-down governance based on conformance, market is top-down governance based on incentives, and network governance is based on interconnected relationships.

achieve results. Network-based governance seeks *partners and cocreators* and relies on trust to achieve outcomes (Meuleman, 2008). Mixing these varied values and expectations, even when addressing common objectives, generates conflicts among stakeholders. These three orders of complexity based on natural capital, the varied social and economic values of stakeholders, and their organizational structures combine to create a complex agriculture landscape system.

2.2 The complex agriculture landscape system

The agriculture system of today emerged as complex systems do, from the interactions of all the system components and stakeholders (Mitchell and Newman, 2002). As a complex system, it is an ensemble of many elements which are interacting in a disordered way, resulting in robust organization and system memory (Ladyman and Lambert, 2012). Like most all complex systems, it is a composition of simple, complicated, and complex subsystems.

2.2.1 The simple and complicated

Simple and complicated systems are manageable with central control and their outcomes can be predetermined. For example, a simple task such as turning a key to start a tractor is a simple system task. Using the tractor to plant a crop or construct a waterway in a field is a complicated system task. It is a complicated process based on a variety of scientific knowledge sets.

In a simple system, a process can be followed and repeated with relatively little expertise and be expected to produce uniform results. In complicated systems, a higher order of expertise is often required and a variety of disciplines or expertise may need to be drawn upon in order to produce a successful result. Once that result is achieved, it is—in most cases—replicable (Glouberman and Zimmerman, 2002). With time, experience, and repetition, planting a crop or constructing a waterway and knowing when the task is successfully completed is knowable. Addressing a simple and complicated system is considered a tame problem.

2.2.2 The complex

Complex systems differ from simple and complicated systems. The distinction between complicated and complex systems is important in evaluating problems as complicated and complex systems require different methods of analysis. Good evaluation of a complicated system involves repetition, replication, predictability, and infinite detail. Good evaluation of a complex system involves pattern description, contextualization, and dynamic evolution (Williams and Van 't Hof, 2014).

In a complex system, outcomes are an emergent quality of the system which can be influenced, but not controlled, by stakeholders (Ng and Andreu, 2012). Many unknowns remain and the systems are in a state of constant flux and unpredictability. There are no right answers, only emergent behaviors (Snyder, 2013).

In complex systems, the individual elements are influenced directly by the behavior of the system as a whole, and at the same time their interactions lead to the emergent behavior at the aggregate level of the system. The *common sense* connection between the size of an event and its consequences no longer holds. Small changes have the capacity to trigger large-scale events (Farmer et al., 2012).

A complex system can only be understood as a whole; it is different from the sum of its parts and often involves a socioeconomic aspect. The system itself emerges from the interaction of the parts making it dynamic, probabilistic, and unpredictable (Williams and Van 't Hof, 2014; Farmer et al., 2012). To better understand complex, wicked problems and their components, Williams and Van 't Hof (2014) suggest drawing a rich picture (see Box 2.1) to define the complex system as it *is*.

BOX 2.1

Rich pictures are a part of soft system methodology, a systemic approach developed by Peter Checkland for tackling real-world problematic situations, the kind of messy problem situations that lack a formal problem definition.

The rich pictures provide a mechanism for learning about complex or ill-defined problems by drawing detailed ("rich") representations of them. Typically, rich pictures consist of symbols, sketches, or "doodles" and can contain as much (pictorial) information as is deemed necessary (Avison et al., 1992).

2.2.3 The system as it is

Rittel and Webber (1973) describe wicked problems as discrepancies between the state of affairs as it "is" and the state as it "ought to be." To begin a problem-solving effort one must create a representation of the problem to make the solution transparent (Simon, 1996) or help illuminate important dimensions of a problem (Baldwin and Woodard, 2009). In this case, the primary dimensions include the natural capital, stakeholders, and organizational governance.

Drawing a rich picture is one method to identify components, stakeholders, and boundaries of the [agricultural sustainability] system as it is (Simon and Bell, 2008; Williams and Van 't Hof, 2014). Since no endeavor is boundless, system boundaries must be consciously chosen to determine which components are included within the system. This process deems what is relevant, who is important, what processes are accounted

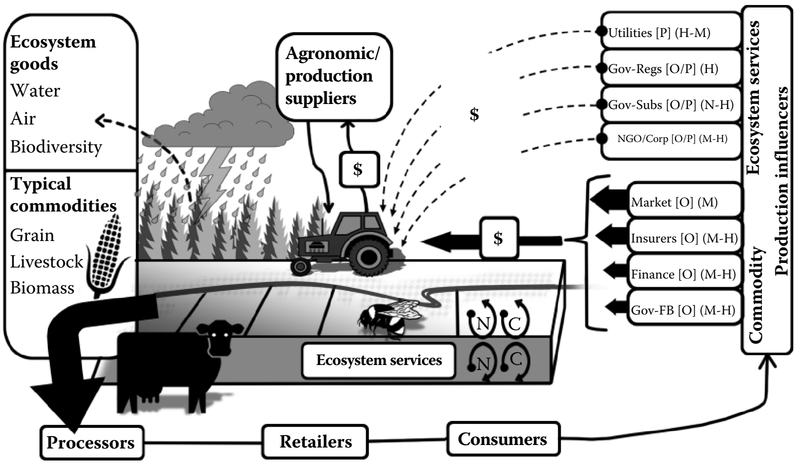

Figure 2.3 A *rich picture* is used to depict the boundaries and components of the agriculture landscape production system as it currently exists. The landscape and its features are the natural capital that produces ecosystem goods and ecosystem services. The typical food and fiber commodities are sold to processors and on to consumers. The activities of land managers directly influence the production of commodities and ecosystem goods and services. Indirect influence on commodity production is applied from government, financial institutions, insurers, and the market to produce commodities in a fairly organized and strong manner. Commodity production influencers are depicted as using outcome-based accounting and market-hierarchy governance styles. Indirect influence on ecosystem service production is applied from government, NGOs, corporations, and utilities in a less organized and relatively weaker manner. Ecosystem service production influencers generally use a mix of outcome and practice-based accounting systems and a mix of governance styles.

for, and what values are expressed (Williams and Van 't Hof, 2014). The system boundaries shown in Figure 2.3 are defined by the natural capital components, the stakeholders directly and indirectly influencing the land management decisions, and the governance styles adopted by the organizations.

The system as is contains the natural capital that produces ecosystem goods and ecosystem services (see Box 2.2). The system supply chain is represented by processors, retailers, and consumers that influence numerous sectors and organizations described here as commodity and ecosystem service production influencers. The commodity production influencers rely on outcome-based [O] accounting systems (direct measurement or indices) and market and hierarchy governance styles. The relatively uniform structure generates a concerted approach to valuing commodity production. The ecosystem service production influencers consist of government regulators and subsidy programs, utilities, NGOs, and corporations. They rely on outcome and practice-based [O/P] accounting systems and a mix of governance styles. This relatively nonuniformed structure results in low and diffuse values for ecosystem services. The production group consists of the farmers and businesses that directly support the production of both commodities and ecosystem services depending on the market and policy signals they respond to.

BOX 2.2 ECOSYSTEM GOODS AND ECOSYSTEM SERVICES

The definitions of ecosystem goods and ecosystem services vary widely and are discussed in more detail in Chapter 3. In this text, the definition of ecosystem goods and services are aligned with the traditional economic description where a service is an *intangible process* that cannot be weighed or measured, and a good is a *tangible output* of a process that has physical dimensions.

Ecosystem services are the less tangible functions and processes of natural capital that consisted of pollination services, nutrient and carbon cycling, and water purification. Ecosystem services are seldom included within economic transactions. “Ecosystem goods” is a broad term representing goods often not traded such as water, air, and biodiversity as well as typical commodities that enter the food supply chain.

With this definition, the water flowing from the landscape is an ecosystem good, whereas the landscape’s process of cleansing the water is an ecosystem service. Likewise a bushel of grain is a good and the nutrient cycling of the soil and crop is an ecosystem service.

2.2.3.1 Natural capital

The natural capital of the agriculture landscape consists of soils, topography, biology, climate, and the overall functions of the agriculture ecosystem. The natural capital outputs (discussed in more detail in Chapter 3) are categorized as ecosystem goods and ecosystem services (Box 2.2). The rich picture depicts two types of ecosystem goods: (1) traditional commodities (grain, livestock, and biomass) that are processed into foods and products for consumers and (2) consumable, but generally noncommoditized goods such as water, air, and biodiversity that are vitally important to the economy, ecology, and human welfare. The flow of traditional commodities is depicted by the large downward facing arrow in the lower left portion and the flow of the consumable, but generally noncommoditized goods are depicted by the dashed arrow in the upper left portion.

The other category of natural capital outputs include ecosystem services, the processes and functions of the agriculture landscape that are rarely included within economic transactions. These include nutrient cycling, carbon sequestration, pollination, erosion control, water purification, and other bio-geo-chemical functions of a landscape. They are depicted as diffuse and distributed outcomes from the landscape as a whole.

The production of ecosystem goods and services is directly dependent on the management activities of the land managers whose decisions are influenced by numerous system stakeholders.

2.2.3.2 System stakeholders

System stakeholders consist of producers, processors and consumers, and corporate, government, NGO, and utility entities each with diverse sets of values and interest in agriculture landscape management.

Generally speaking, in the system as it *is*, there are well-established institutions, cultural norms, and values that support the production of traditional commodities. This group is represented in the lower right-hand portion of the figure and is referred to as the commodity production influencers. There are also growing, but far less established and organized group of institutions associated with supporting the production of ecosystem services. This group is represented in the upper right-hand portion of the figure and is referred to as the ecosystem service production influencers.

2.2.3.3 Production group

The production group is the land practitioners such as farmers and businesses directly involved in the production of ecosystem goods and services. Those in the production group are often described as *price-takers* and *policy-takers*, meaning they have little or no control on setting commodity prices and must work within the framework of government policies and the emerging corporate policies regarding sustainability practices. The producers' decisions are influenced by market price signals, risk factors and risk mitigation options, and government and corporate policies.

Ultimately, it is the actions of land managers, within the context of weather and environmental forces, which result in the production of various quantities and qualities of ecosystem goods and ecosystem services. Figure 2.3 also portrays the relative influence the production group receives from the production influencers. The values from the ecosystem service influencers are diffuse and low, and the values from the commodity influencers are combined and greater.

2.2.3.3.1 Production influencers Commodity and ecosystem service production influencers exert influence directly toward the production group. In reality, these two groups are not delineated as distinctly as illustrated, as their influence comes from a variety of sources with, at times, the intent to achieve both objectives. The processor–retailer–consumer grouping has a long-standing interest in abundant production and low food cost. Due to the relatively recent sustainability movement, many of the entities within this group now have sustainability interests as well.

Food processors provide a close link to commodity production by purchasing grains and livestock and generating current and future price levels or market signals. Consumers are adopting new values associated with food, causing retailers to seek ways to provide low-cost foods while considering their sustainability characteristics. This influence is passed on to commodity production influencers and ecosystem service production influencers.

2.2.3.3.2 Commodity production influencers The grain commodity market, crop insurers, production financers, and government subsidies provide a unified and additive approach in supporting the production of traditional commodities. Each sector in the production influencers group has a vested interest in generating maximum production of grain commodities. This common objective, over time, has generated complementary policies and strategies to support the production group in producing traditional commodities. This established and unified approach is illustrated by heavy and combined arrows leading to the production group.

Prior to the sustainability movement, the food processors, retailers, and consumers had little interest other than food price and so the commodity production influencers, for all intents and purposes, were the only influence the production group received.

2.2.3.3.2.1 Ecosystem service production influencers The ecosystem service production influencers, unlike the commodity production influencers, are rather diffuse in their influence as represented by dashed, unconnected lines. Of the four sectors represented, the Gov-Subsidy sector has applied influence the longest. The United States Department of

Agriculture (USDA) conservation incentive programs began in the 1930s with the creation of the Soil Conservation Service and the local conservation districts. In the 1970s, the Clean Water Act was passed and was followed by the sustainability movement of the 1980s.

This influence has continued to grow with support from NGO efforts to influence policy and social norms, and from corporate sustainability supply chain initiatives to source sustainably grown commodities. Generally, these stakeholders support land management strategies that generate cleaner water, improve soil health, sequester carbon, and support wildlife and other nonmarket goods and services related to the environment.

Today, the system as it *is* has a far greater number of sustainability stakeholders influencing the agriculture production system than decades ago, but the effects of the influence are mixed. This is due, in part, to the varied scope and scale of natural capital outputs and the challenges it causes for policy makers and market developers. These produce wicked challenges that overwhelm the efforts of the ecosystem service production influencers.

2.2.3.3.2.2 Seemingly infinite complexity Natural systems, such as agroecological systems, are not just a compilation of complicated subsystems, but are highly complex systems when viewed in terms of their number of constituents, the dynamic structure of their interconnections, the number of possible interactions, and the consequences of outside influences (Fisher, 2006). The intertwining of social, economic, and ecological aspects of agricultural landscape sustainability creates a scenario with seemingly infinite complexity.

To put this level of complexity into context, Ruhl et al. (2007) apply mathematics of permutations. To sustain an agricultural landscape, it must be managed in a way that produces abundant foods while maintaining the productivity of the natural capital. Ruhl et al. (2007) state that the number of potential land use patterns to accomplish this is related to the number of fields within a geographical area raised to the number of land-use options. For example, if a region contained 1000 fields and each producer has the option to plant five types of crops, the potential number of land-use patterns relative to crop production would be 1000 to the power of 5 or 10^{15}. Within this large number of possibilities, one landscape pattern emerges each year as farmers attempt to achieve their production goals within the context of market forces and government policies. While crop production does fluctuate each year, the market signals and government policies of the system as it *is* has been generally successful at creating a landscape pattern out of the 10^{15} possibilities to produce sufficient crops.

To put this scenario in the context of agricultural landscape sustainability, one could add several conservation practices and activities to the five crop options to calculate the number of potential landscape patterns within the context of a sustainable landscape. Incorporating five additional land management options into Ruhl's equation results in 10^{30} land-use pattern (1000 to the power of 10) possibilities. Obviously, many potential patterns would suffice for producing a sustainable agriculture landscape, but a process still needs to be in place to *choose* one. Within this socioeconomic context, it is apparent how the traditional top-down approach can be costly and be overwhelmed in the quest to determine a sufficient landscape pattern for these 1000 fields.

2.2.3.3.2.3 Undefinable property rights Unlike traditional commodity crops, ecosystem services do not have defined property rights. Without recognized property rights and access to markets, [natural capital] assets become "dead capital" unable to generate returns over and above that associated with their direct use. This ownership issue arises as ecosystem services have the characteristics of being defined as a *public good* rather than a *private good*. Public goods lack a clear definition and allocation of rights (Landell-Mills and Porras, 2002). Public goods are distinguished by their nonexcludability and nonrivalry status.

Nonexcludability means that consumers cannot be prevented from enjoying the good or service in question, even if they do not pay for the privilege. For instance, it is difficult, if not impossible, to exclude downstream communities from benefiting from improved water quality associated with sustainable practice upstream.

Where goods are nonrival, the consumption of a good or service by one individual does not reduce the amount available to others. In this situation, there is no competition in consumption since, theoretically, an infinite number of consumers can use the given quantity supplied. An example of a nonrival ecosystem service is carbon sequestration. Once carbon is sequestered, the global community may benefit from this in terms of a reduced threat of global warming.

In the system as it *is*, many ecosystem goods and services remain undefined with regard to property rights. And in one way or another, all environmental and natural resource problems associated with overexploitation or underprovision of public goods arise from incompletely defined and enforced property rights (Libecap, 2009).

2.2.3.3.2.4 Undermine market formation Where nonexcludability and nonrivalry exist, they undermine the formation of markets since beneficiaries of the good or services have no incentive to pay suppliers. As long as an individual cannot be excluded from using a good, they have little reason to pay for access. Similarly, where goods are nonrival, consumers know that where someone else pays, they will benefit. In both cases, beneficiaries plan to *free-ride* based on others' payments (Kim et al., 1980). And, where everyone adopts free-riding strategies, willingness to pay for public goods will be zero and will undermine markets.

2.2.3.3.2.5 High transaction costs Trading in any market will not occur if the transaction costs exceed the benefits of a potential trade. Transaction costs include not only components of paperwork, verification, auditing, commissions, and other activities surrounding the sale of an item, but also the costs associated with the creation and operation of markets. Costs of market creation include defining property rights, setting up exchange systems, educating market participants, establishing monitoring and enforcement mechanisms, and building confidence in the system. Market operation includes costs of information gathering, negotiation, contract formulation, monitoring, and enforcement.

Ecosystem service credit-trading programs are characterized by higher transaction costs because trading partners may be widely distributed and there may be uncertainty in market components (Abdalla, 2008). The system as it *is* carries a high level of market uncertainty in measurement, valuation, verification, and defining property rights.

2.2.3.4 Organizational governance styles

The third wicked aspect of the system as it *is* involves the governance styles of the stakeholder organizations. Governance provides the framework for how an organization functions, gathers information, and makes decisions. In Figure 2.3, governance styles of production influencers are shown as well as how they account for the natural capital outputs and outcomes of interest.

The letters in the set of parentheses describe the primary governance style of the organizations. "H" is for hierarchy, "M" for market, and "N" for network governance styles. Since few organizations have strictly one type of governance style, the identifiers chosen are those that best represent the predominant governance style of the organization. Market and hierarchy governance are the predominant styles used by the commodity production influencers and a mix of governance styles is used by the ecosystem service production influencers.

Governance styles do influence which accounting strategies are adopted, as it relates to how information is gathered. That correlation is not made here, but accounting strategies are noted. The accounting strategy of the organizations are described in the first set of brackets ([ ]) and it includes an "O" for outcome-based, "P" for practice-based, or "O/P" to denote the use of the combination of the two accounting methods. For example, outcome-based accounting may be based on a direct measurement such as kg/hectare or a model calculation such as a water quality index that uses soil type, land slope, vegetation, climate, and other environmental and management factors to calculate the production of a particular quality and/or quality of water or other environmental benefit. A practice-based accounting system would identify particular practices, such as if a grass waterway is installed and functioning, or if a particular tillage practice is used.

Practice-based accounting is applied where measurements are difficult to obtain or due to traditional preference. Of course, the use of practice-based accounting, such as when a field was cultivated, would not be considered a viable option account for the production of grain where quantity and quality is easily measured and tested.

The commodity production influencers have adopted a relatively uniform outcome-based system using the common governance styles of market and hierarchy. The ecosystem service production influencers have adopted different accounting strategies and a mix of governance styles. This mix of accounting and governance strategies of the ecosystem service production influencers and the commodity production influencers is a fundamental aspect of the wicked problem.

The results are low and diffuse values, and high and multiple transaction costs for ecosystem services. This issue is compounded if one considers the ecosystem service production influencers must compete with the commodity production influencers, who over time have created multiple value streams for commodities and reduced the transaction costs associated with their markets.

2.3 *Transdisciplinary challenge*

The state of the system as it *is* consists of many organizations, sectors, and disciplines operating from isolated, silo-like perspectives. These traditional disciplinary approaches have had a considerable and overwhelmingly positive impact on the world and have provided scientists with methodological approaches and technologies (Brown, 2010). In addition, they provide shared concepts and language and accreditation to practitioners within their fields. Yet, it is increasingly recognized that, to address many of our current problems, this traditional approach is not sufficient (Stock and Burton, 2011).

The complexity of today's problems increasingly demand that scientists [and policy makers] move beyond the confines of their own discipline [and sectors], especially for problems concerning sustainability as natural, social, and human issues are tightly connected (Tappeiner et al., 2007). Initiating these changes and achieving sustainability objectives inherently requires transdisciplinary attempts (Stock and Burton, 2011).

Brown (2010) stated any resolution to socially embedded wicked problems calls for changes in that society in the form of new governance, and new methods of research and decision making based on transdisciplinary research. This does not entail asking researchers to reject the powerful tools and strategies developed by individual disciplines that led to disease reduction, an increase in world food production, and putting a man on the moon. It does ask for open transdisciplinary modes of inquiry that meet the needs of the individual, the community, the specialist traditions, and influential organizations. It requires an evolution in disciplinary thinking and imagination (Brown, 2010).

2.3.1 Disciplinary evolution

During the four centuries of the industrial revolution, analytic modes of scientific inquiry were developed to address technical problems and their social consequences. These became the academic disciplines that came to dominate educational institutions and research traditions (Brown, 2010). Hunt and Thornsbury (2014) describe this evolution from disciplinary to multidisciplinary, to interdisciplinary, and to transdisciplinary research. Figure 2.4 illustrates the evolutionary stages of disciplinary research. Choi and Pak (2006) define these disciplinary approaches with the common words of additive (multidisciplinary), interactive (interdisciplinary), and holistic (transdisciplinary).

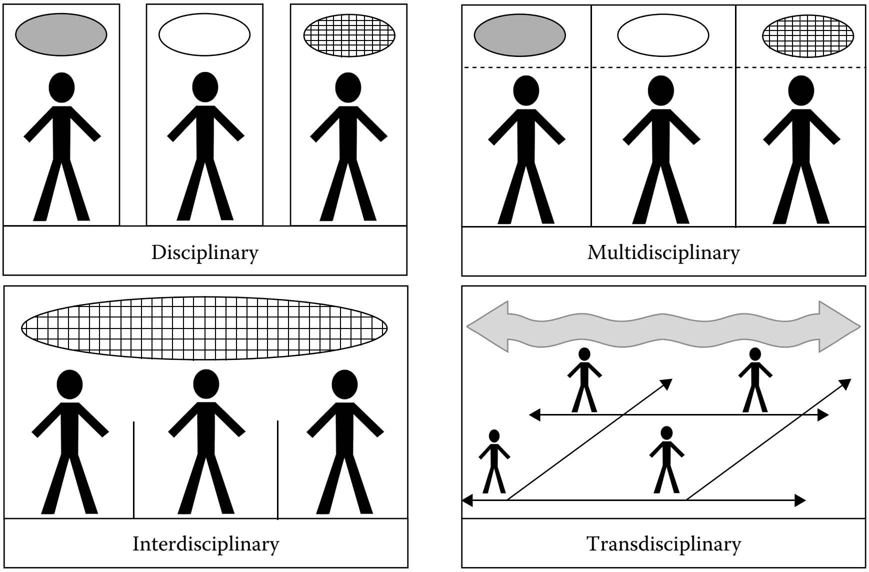

Figure 2.4 The four stages represent the evolution in disciplinary research. Disciplines acting singularly in their research create knowledge, theory, language, and boundaries for a particular area of study. As issues become more complex, multiple disciplines exchange knowledge with each other but do not integrate. Interdisciplinary research crosses disciplinary boundaries and results in the development of integrated knowledge and theory. Transdisciplinary research crosses disciplinary and academic boundaries with common goal setting. It is the most recent and challenging research method as it consists of academic and nonacademic participants addressing ongoing, real-world issues. This open-ended scenario is represented by an open-ended platform depicted as potentially unlimited and ongoing. (Adapted from Hunt, F. and Thornsbury, S., *Open J. Soc. Sci.*, 02(04), 340–351, 2014.)

A disciplinary approach involves goal-setting within one discipline with no cooperation or knowledge sharing. Its purpose is to develop new disciplinary knowledge and theory (Hunt and Thornsbury, 2014). A multidisciplinary approach is the most basic level of involvement. It refers to different disciplines working on a problem in parallel without challenging their disciplinary boundaries. It is taken to be a combination of specializations for a particular purpose (Brown, 2010). Figure 2.4 shows the first phase of disciplinary interaction. Goal-setting occurs under a common theme with loose cooperation to exchange knowledge.

An interdisciplinary approach brings about reciprocal interaction between disciplines and blurs the disciplinary boundaries in order to generate new common methodologies, perspectives, and knowledge (Choi and Pak, 2006). It is the common ground between two specializations that may develop into a discipline of its own, such as the convergence of biology and chemistry (Brown, 2010). Interdisciplinary is an integration of knowledge and theory (Hunt and Thornsbury, 2014).

A transdisciplinary approach involves scientists from different disciplines as well as nonscientists and other stakeholders and, through role release and expansion, transcends the disciplinary boundaries to look at the dynamics of whole systems in a holistic way (Choi and Pak, 2006). It crosses not only disciplinary, scientific, and academic boundaries, but integrates nonacademic participants to develop integrated knowledge among society (Hunt and Thornsbury, 2014). In this sense, transdisciplinary efforts are the highest form of integrated project, involving not only multiple disciplines, but also multiple *nonacademic* participants (e.g., land managers, user groups, the general public) in a manner that combines an interdisciplinary strategy with participatory approaches (Stock and Burton, 2011). Figure 2.4 illustrates a transdisciplinary approach as a broad platform with an ongoing solution resolution process that is open to all disciplines, social sectors, and entrepreneurs. This dynamic and open process is applicable to resolving the ongoing and open-ended wicked problems of agriculture landscape sustainability.

2.3.2 *Application challenges*

While transdisciplinary efforts are probably the most desirable, they are also the most difficult to obtain. Some researchers are skeptical about whether it can be achieved at all, causing Stock and Burton (2011) to refer to it as the holy grail of research, where achieving transdisciplinary landscape research is an exception and where even interdisciplinary solutions are seldom reached.

The review of transdisciplinary studies by Brandt et al. (2012) supported these findings and in particular the challenge of engaging nonacademic practitioners. In the peer-review published case studies, only 9 of the 236 studies (3.8%) involved practitioners in the entire transdisciplinary process from problem definition to implementation. Scholars involved in transdisciplinary projects must be willing to transcend and integrate disciplinary paradigms with the goal of finding a unity of knowledge beyond individual fields of study. As an evolving field of research with varied definitions and strategies, several challenges to applying transdisciplinary projects remain (Lang et al., 2012).

To overcome these challenges, Brandt et al. (2012) identified five key needs when undertaking transdisciplinary approaches to sustainability sciences:

1. *Establish coherent framing*. A lack of a shared framing for a particular issue results in scientists and practitioners addressing the issue with differing strategies and not producing robust knowledge to solve sustainability problems.
2. *Integration of methods*. Integrating different disciplinary methods and developing research methods that enable learning processes is crucial for an effective science–society interface.
3. *Research process and knowledge production*. Sustainability science research processes must cater to all participants to gather the knowledge related to the process phases of problem definition, analysis, and generation and application of solutions to real-world problems.
4. *Practitioners' engagement*. The link between practitioners and scientists is a crucial element for information exchange, collaboration, and practitioner empowerment to make decisions.
5. *Generating impact*. The challenge to intensively engage with practitioners at the scale needed to produce change tends to constrain the focus of transdisciplinary research to local or regional scales.

2.3.3 *A wicked resilient problem*

The long enduring system as it *is* is resilient while harboring three wicked principle problems of landscape sustainability:

1. Outputs and outcomes of the system vary in scope and scale.
2. Stakeholders have disparate values of and accounting processes for the outputs and outcomes of the system.
3. Stakeholder organizations within the system have inherently conflicting governance styles.

Each of the generic principles of themselves produces challenges to resolve any problem and together they create a wicked socioecological issue. To resolve this, one must understand the fundamental principles of these wicked problems to enable a transdisciplinary approach that transcends each of the principle causes.