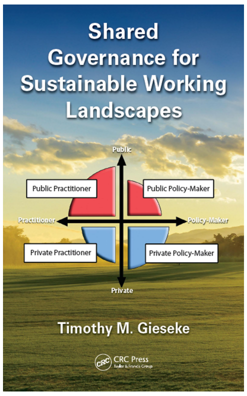

Shared Governance for Sustainable Working Landscapes

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Natural capital outputs and outcomes

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chapter three

Natural capital outputs and outcomes

The wicked challenges associated with measuring and accounting for natural capital outputs and outcomes is, in part, founded in the historic and limited acceptance of natural capital as an economic capital (Bennun et al., 2014). Harrison (1989) states this basic difference is that environmentalists regard natural resources as assets analogous to man-made capital, whereas they are treated as free gifts of nature in the national economic accounts. Boyd and Banzhaf (2007) add that the lack of a unified definition for ecosystem services is a significant reason for their exclusion. This has resulted in multiple definitions from the scientific community on what an ecosystem service *is*, which undoubtedly leads to confusion in determining how to account for and incorporate their value into the economic system.

3.1 A natural economic capital

Wealth is created through factors of production, or so-called capitals that are used to create goods or services. The list can vary, but the following represent five major economical capitals:

- Financial capital: money used by entrepreneurs and businesses to make products or provide services
- Infrastructural or physical capital: factories and other man-made enterprises used as a means of production
- Human capital: workers' skills and abilities in regards to their contribution to an economy
- Social capital: the value of social networks to society and the human economy
- Natural capital: the resources of an ecosystem that yields a flow of goods and services, also called ecosystem services

Hence, the agriculture landscape is synonymous with natural capital. Natural capital underpins all other types of capital (man-made, human, and social) and is the foundation on which the economy, society, and prosperity is built as it produces flows of ecosystem services that benefit people, business, and society (Natural Capital Coalition, 2015). It is the elements of nature that produce value (directly and indirectly) to people, such as the stock of forests, rivers, land, minerals, and oceans. It includes the living aspects of nature as well as the nonliving aspects such as minerals and energy resources.

3.1.1 Not a new idea

The idea that natural capital is an economic capital can be traced back to Smith's (1952) *Wealth of a Nation* in 1776. In this first economics book, he made a comparison of natural capital of a farm to man-made capital in his statement, "An improved farm may very justly be regarded in the same light as those useful machines which facilitate and abridge labor. An improved farm is equally advantageous and more durable than any of those machines, frequently requiring no other repairs than the most profitable application of the farmer's capital employed in circulation." Regarding the productivity of farming, Smith (1952, p. 157) states that after all their labor, a great part of work always remains to be done by her [nature]. Classical nineteenth century economists such as Ricardo and Faustmann also incorporated the concept of natural resources as capital in economic theory (Fenichel and Abbott, 2014).

In the 1980s Longva was commissioned by Norway's Central Bureau of Statistics to create an economic classification of natural resources. The nonrenewable mineral and energy resources were classified as finite commodities. The renewable biological resources such as fish, forests, and agricultural products were classified as conditionally renewable commodities. As a conditionally renewable resource, their production is dependent on the condition of the natural capital such as the fertility of soil, quality of water, number of reproductive fish stocks, and quality of air.

A third classification was renewable, inflowing resources, associated with the sun and its interaction with the earth's surface and atmosphere. These resources are not traded as commodities and are infinite in supply.

A fourth classification was the environmental resources of air, water, soil, and space. As a rule, environmental resources are not consumed when used in the production process, but as the quality of the resource varies it alters production capacity (Longva, 1981). These are conditionally renewable resources, whose productivity and usefulness, and so their economic values, are dependent on the integrity of the resource.

Repetto (1988) makes a similar, albeit more modern analogy, by stating that as man-made assets (buildings and equipment) age, they become less productive and their worth decreases. To maintain their original or optimum capacity, money is set aside for their replacement in order that the income flowing from their use is sustainable. But the value of natural assets also falls if the assets are depleted. Thus, in the same sense that a machine depreciates, soils depreciate as their fertility is diminished, since they can only produce at higher costs or lower yields. Repetto states natural resource depreciation needs to be treated as asset depreciation in order to put man-made capital and natural capital on the same footing.

Since Longva's (1981) economic classification of natural resources, the field of ecological economics has grown along with the desire to account for and value the *processes* and *functions* of natural capital.

3.1.2 The landscape as a living factory floor

The agriculture landscape has inherent structures, processes, and functions specific to its geography and geology. These inherent attributes are affected by how it is managed. This is analogous to physical or built capital, such as factories. Factories have an inherent structure that supports the processes and functions specific to their design objectives. The outputs and conditions of natural or physical capital are conditionally renewable that are affected by management, which is in turn influenced by how it is accounted for and valued.

3.1.2.1 An automobile factory

For man-made capital, such as an automobile factory, the processes and functions of the factory are easily identified. The price of a car includes the costs of the processes and functions and the structure of the car manufacturing plant. If the factory's equipment degrades, the processes and functions of the factory can no longer produce cars or the factory becomes less efficient in the production of cars. To regain the capacity, financial capital must be reinvested into factory equipment. The accounting strategies for physical capital are well-established business processes as the price of a car includes within it the price of the steel, labor, interest rates, the cost of the factory, computers, the engineering, and the numerous inputs that are needed to construct a car.

To get more cars, people have to demand them (with adequate payment) and in delivering those cars, the processes, functions, and structure of the factory are developed and built. The person who bought the car is also *buying* the processes and functions so that the structure of the manufacturing plant has the capacity to produce cars. The person who wants a car is dependent, indirectly, on those processes and functions of that physical capital structure.

If, in some odd world or culture, cars could not be purchased but were considered public goods, then no one would make cars unless some other component of the car manufacturing plant was valued.

If the processes and functions of the manufacturing plant were valued adequately and there was an efficient method to account for and exchange value for these processes and functions, then attempts to develop the capacity of that manufacturing plant to meet the demands for cars would be valued. This odd scenario to value physical capital as a means to generate the desirable outputs and outcomes of cars is the challenging scenario for valuing natural capital, that is, if one wants to generate the desirable outputs and outcomes of cleaner water and other environmental benefits.

3.1.2.2 *A drinking water factory*

The purpose of using the *factory floor* as an analogy to the agriculture landscape is to compare how the same components of natural capital, such as the processes, functions, structures, outputs, and outcomes, are valued relative to physical or built capital.

Since 1909, the Seattle Public Utilities has relied on the Cedar River Watershed to purify drinking water for its residents. The landscape, trees, soil, and biology, the bio-geo-chemical processes of the ecosystem, captures, treats, stores, and transports drinking water to Seattle residents. The Seattle Public Utilities views this watershed, in many respects, as their drinking water factory. To mimic these processes, the Seattle Public Utilities would have to build a $200 million filtration plant along with the conveyance system to filter and deliver the city's water supply and budget annual operating and maintenance costs of $3.6 million per year (Cosman et al., 2012).

Despite these comparisons made on scientific principles, the watershed's components related to the delivery of drinking water are not considered economic assets in the same manner as the processes that are constructed from concrete and steel. Cosman et al. (2012) state that if natural capital assets were accounted for, investments in watersheds such as controlling invasive plant or insect species, purchasing additional land that is threatened by development, or helping farmers minimize runoff of animal waste and fertilizer into the watershed would sustain this natural infrastructure resource.

3.2 *The conditionally renewable earth factory*

To sustain the natural capital outputs of the conditionally renewable resources, the processes, functions, and structures must be properly managed. Since the Earth, as a whole, could be considered a *living* factory, further delineating the ecological structure of the earth factory is needed. At the largest scale, the earth consists of regional biomes with each containing multiple ecosystems. As a living system, ecosystems are built from the bottom up with the processes leading to the structure that support the functions that produce the outputs.

3.2.1 Biomes

Biomes, or "major life zones," are large geographic region of the earth's surface with distinctive plant and animal communities. There are both terrestrial, or land-based biomes, and aquatic biomes. A biome may be spread over a wide geographic area, or as a grouping of many ecosystems that share similar environmental features and plant and animal communities (Caris et al., 1996). Biomes represent a superficial and somewhat arbitrary classification of ecosystems. These are not distinct geographical features such as a mountain range and, therefore, biologists are not unanimous in how they classify biomes or in the number of biomes. Commonly recognized biomes include the following:

- Land-based biomes
  - Tundra (permafrost regions)
  - Taiga (high-latitude forested regions)
  - Temperate deciduous forest
  - Grasslands
  - Deserts
  - Tropical rainforests

- Water-based biomes
  - Marine
  - Estuary
  - Fresh water

Using the factory analogy, the biomes are not the production facilities, but define the regional economy (ecology) and the resources available that support the ecosystems.

3.2.2 Ecosystems

Ecosystems act as the factory unit. They consist of abiotic (nonliving) and biotic (living) components. Abiotic components are sunlight, temperature, precipitation, water, and soil parent material. Biotic components consist of plants, herbivores, carnivores, omnivores, and detritivores (generally those smaller organisms that consume decaying plants). As noted, the entire biosphere of Earth is an ecosystem since all these elements interact. But for analysis and assessment, it is important to adapt a pragmatic view of ecosystem boundaries.

The Millennium Ecosystem Assessment (MEA) developed 10 reporting categories to provide a useful framework for understanding ecosystems relative to human well-being (Alcamo and Bennett, 2003):

- Cultivated: lands dominated by domestic plant species, used for and substantially changed by crop, agroforestry, or aquaculture production
- Dryland: land where plant production is limited by water availability and the dominant uses are large herbivores, including livestock grazing and cultivation
- Forest: lands dominated by trees that are often used for timber, fuel wood, and non-timber forest products
- Marine: ocean with fishing typically a major driver of change
- Coastal: the interface between ocean and land extending into the land to include all areas strongly influenced by proximity to the ocean
- Inland water: permanent water bodies inland from the coastal zone, and areas whose ecology and use are dominated by the permanent or seasonal occurrence of flooded conditions
- Island: lands isolated by water with a high proportion of coast to inland
- Mountain: steep and high lands
- Polar: high-latitude systems frozen for most of the year
- Urban: built environments with a high human density

Defining the boundaries or identifying categories of ecosystems is not an exact science as those definitions are influenced by what the intentions of the delineation are. The MEA categories do not have definite boundaries and often overlap. The MEA uses overlapping categories because this better reflects real-world biological, geophysical, social, and economic interactions, particularly at these relatively large scales.

3.2.2.1 Processes

Within all ecosystems, certain processes occur to sequester, transform, and move energy and materials through the ecosystem. Ecosystem processes include the following (Ruhl et al., 2007):

- Photosynthesis
- Plant nutrient uptake
- Microbial respiration
- Nitrification and denitrification
- Plant transpiration
- Root activity
- Mineral weathering
- Vegetative succession
- Predator–prey interaction
- Decomposition

These processes operate within biological and physical characteristics and constraints. Energy movements are essentially one-way flows that prevent the reuse or recycling of energy. Nutrients, on the other hand, can circulate through different components of an ecosystem and create nutrient cycles and pools. The study of ecology, at its most fundamental level, is quantifying the factors that regulate energy transformation and nutrient cycling within the particular ecosystem defined.

Processes, such as photosynthesis, can be accounted for at multiple scales such as at the level of an individual leaf or within the canopy of a forest. Therefore, defining ecosystem processes must also entail defining the scale at which the process is going to be measured. It should be noted that these fundamental processes exist in all ecosystems whether that is a cornfield in Iowa or the rainforest of Brazil.

A factory analogy would be to consider the processes of man-made capital, such as a factory using electricity, switches, conveyor belts, chains, hydraulics, computers, robots, and other generic processes that other manufacturing plants would use to create their particular products. Each is considered a generic process that exists in virtually all factories, but depending on their particular function, produce a variety of outputs.

3.2.2.2 Functions

Ecosystem functions are the complex physical and biological cycles and interactions that underlie what is observed as the natural world (Brown et al., 2007). The functions of all ecosystems rely on the same biological and chemical processes, but different biome conditions (such as location, soil parent material, climate, etc.) create different functions.

For example, the processes (photosynthesis, transpiration, etc.) in the Iowa cornfield and the rainforest are relatively the same, but the functions become quite different. The corn field has the basic function to produce corn, but can also produce clean water, pheasants, and sequestered carbon. The rainforest has the basic function to create a tree canopy habitat and all the interrelations that make it a rainforest. The same processes within the context of different environments create different functions.

To make a more comparable scenario: a corn field in Iowa that is adjacent to a prairie field has the same processes, location, soil parent material, weather, and climate but they each result in a different function. The ecosystem function is how the processes interact. An analogy would be to consider the functions of two manufacturing plants. One is capable of producing cars and the other dishwashers. Both factories use the same processes (conveyor belts, welding, and hydraulics), but since they are organized differently they have different functions.

3.2.2.3 Structures

Unique to natural systems, the ecosystem functions contribute to the building of the ecosystem's biophysical structure, which in turn supports the functions themselves (Christensen et al., 1996). A crop-management system can create the biophysical characteristics that are advantageous for crop yields. Perhaps more apparent in the rainforest, the structure of the vegetated tree canopy supports the functions of the rainforest. This structure supports the processes and functions of the ecosystem and creates value for humans and their economy. This natural capital system supports the creation and flow of goods and services to humans (Clark, 1995).

3.2.2.4 Outputs and outcomes

The outputs and outcomes that flow from ecosystems are ecosystem goods and ecosystem services. Outputs, or ecosystem goods, are the tangible items such as crops, water, air, and wildlife produced by the agro-ecosystem. While not all ecosystem goods are marketable, they have the characteristics of a physical entity.

Outcomes, or ecosystem services, are the less tangible and most often unmarketable processes such as water purification, nutrient cycling, and pollination. They are the bio-geo-chemical processes of the landscape whose rate and occurrence fluctuates relative to environmental factors and human activities applied to the natural capital. Measuring and accounting for outcomes and outputs is challenging due to the varied nature and interests in the landscape. This is made more complicated as uniform definitions of ecosystem goods and ecosystem services do not exist.

3.3 Varied ecosystem service definitions

Boyd and Banzhaf (2007) noted that a brief survey of definitions reveals multiple, competing meanings of the term *ecosystem service*. This is problematic because environmental accounting systems increasingly are in need of a process and unit strategy to track and measure outputs. The development and acceptance of welfare accounting (i.e., gross domestic product) and environmental performance assessment are hobbled by the lack of standardized ecosystem service units.

Since many stakeholders bring multiple perspectives to landscape sustainability, it is inherent that many definitions and accounting processes emerge. Four prominent strategies include the following:

- All ecosystem outputs and outcomes are categorized under the common heading of *ecosystem services*
- Separately categorizing ecosystem outputs as *ecosystem goods* and outcomes as *ecosystem services*

- Identify outputs based on [geographically based] *service providing units*
- Categorize ecosystem outputs, those ecosystem goods that are directly consumed by humans as *final ecosystem services*

3.3.1 Categorize goods and services as same

The predominant definition today is to refer to both ecosystem goods and ecosystem services as *ecosystem services*. This framework to categorize all ecosystem outputs and outcomes as *ecosystem services* was adopted by the 2003 Millennium Ecosystem Assessment (Alcamo and Bennett, 2003). This strategy is still widely applied, although it is not considered a universally accepted method (Haines-Young and Potschin, 2009). Costanza et al. (1997) used this framework in determining the value of the world's ecosystem services and in an updated 2014 article addressing the changes in the global value of ecosystem services (Costanza et al., 2014). The papers identified 17 types of ecosystem services, which included both outputs, such as crop production, and outcomes, such as water purification.

The MEA (Alcamo and Bennett, 2003) categorized these ecosystem services as

1. Provisional ecosystem services are the consumable products obtained from ecosystems and include food, fiber, fuel, genetics, biochemicals, and fresh water. Provisional services have the characteristic of being a tangible good that is relatively easy measured, valued, and exchanged.
2. Regulating ecosystem services are benefits that are derived from the processes and functions of ecosystems such as water flows, erosion control, water purification, pollination, and biological controls of insects and disease. Regulating services have the characteristic of traditional services that are difficult to measure, value, and exchange.
3. Supporting ecosystem services are those that are necessary for the production of all other ecosystem services, and their impacts on people are either indirect or occur over a long period of time. These include soil formation, primary production, nutrient cycling, oxygen production, seed dispersal, water cycling, and sufficient biodiversity for evolutionary processes.
4. Cultural ecosystem services are nonmaterial benefits that include ecological and cultural connections that create diverse cultures, religious values, knowledge bases, inspiration, aesthetic values, social relationships, sense of place, heritage, and recreation. Perceptions of cultural services are more apt to differ among individuals and communities than how to value provisional services and regulating services.

3.3.2 *Categorize goods and services as different*

A less prominent definition is based on the traditional economic terms associated with goods and services. Brown et al. (2007) made the distinction that *ecosystem goods* are fundamentally tangible, material, and consumable products such as food, grain, timber, and water generated by the landscape. Like economic goods they are the physical outputs of a process that are produced without interaction with the customers. Goods can be produced to specifications, are relatively stable over time, and their value is associated with the product or unit itself.

Ecosystem services are the less tangible, nonmaterial, and nonconsumable processes such as purifying water, sequestering carbon, and pollination of crops. These ecosystem services occur within and on the landscape and support the production of goods. Like economic services they are intangible processes that cannot be weighed or measured directly and usually require a degree of interaction to have value. Services may vary day-to-day depending on conditions, they can't be stored, and their value is often associated with a location, a good, a person, or site conditions.

She (1997) recognized outputs and outcomes as distinct ecosystem goods and services. She defined ecosystem services as the processes through which natural ecosystems, and the species that make them up, sustain and fulfill human life, as well as support the production of ecosystem goods, such as forage, timber, biomass fuels, natural fiber, and food.

3.3.3 *Identify ecosystem services as service providing units*

Service providing units (SPUs) uses a geographically based definition and identifies values directly associated with the landscape. SPUs have emerged to ensure that the methods to account for ecosystem services link to and support social and economic values. The SPU suggests that instead of just defining a population or organisms along geographic, demographic, or genetic lines, it can also be specified in terms of the services or benefits it generates at a particular scale (Luck et al., 2009). The use of the word "unit" is an attempt to focus attention on the need to spatially quantify the ecosystem service as it relates to an economic value.

The SPU concept is explained with the example of a population of honeybees. At a given density, the bees may provide all the pollination requirements of an almond grower whose production can be quantified to define the SPU in economic terms. Once an SPU has been defined, attention can be given to how changes in this SPU might affect service production and some measure of value. The definition of an ecological unit is a crucial step to facilitating meaningful economic valuation (Kontogianni et al., 2010) and could support payment programs for specific ecosystem services (Sanchirico and Siikamäki, 2007).

Kontogianni et al. (2010) state advances by ecologists in spatially defining the delivery of ecosystem services can provide a framework for quantifying complex ecosystem processes and resulting services.

3.3.4 Ecosystem services as FEGS and BRIs

The fourth definition described is based on the desire to connect ecosystem good and service value directly to economic indices. A group of scientists at the United States Environmental Protection Agency (USEPA) Office of Research and Development has adopted the concept of Final Ecosystem Goods and Service (FEGS) as a foundation for defining, classifying, and measuring ecosystem services (Landers and Nahlik, 2013) based on ecological endpoints.

Ecological endpoints are defined as the "components of nature, directly enjoyed, consumed, or used to yield human well-being" (Boyd and Banzhaf, 2007). As such, ecological endpoints or final goods are what is counted in GDP: the total value of goods that are consumed. The FEGS system excludes intermediate processes, such as ecosystem services and goods that are used to produce final goods. Using ecological endpoints creates a distinction between environmental features that are directly and indirectly valuable to society. The notion of direct versus indirect goods and services is conventional in the economics of traditional markets (Boyd and Banzhaf, 2007).

As a scenario, Boyd and Banzhaf (2007) state forests that sequester carbon and thus contribute to the reduction of climate-related damages would not be accounted for in the FEGS. They state forests may be a final ecosystem service for other reasons but not for climate-related reasons. In this framework, climate-related damages to natural resources are accounted for due to the effect of climate-related sea-level rise on beach recreation. If sea-level rise damages beaches, and thus recreational benefits, that will be captured in our beach-related ecosystem service measures (e.g., beaches themselves). The fact that forests sequester carbon is certainly important but only in an intermediate sense.

They note that from an economic accounting perspective it does not require the measurement of "all that is ecologically important." Rather, one can economize on measurement by monitoring only the end products of complex ecological processes. It is for this reason that FEGS does not include ecological processes or functions. Relying solely on FEGS would not allow measurement of carbon sequestration and the social cost of carbon as an approach (Olander et al., 2015).

For this reason, beneficial resource indicators (BRIs) are proposed to account for less tangible *nonuse* values that can be difficult to quantify and are often excluded. BRIs are measurable indicators that capture this connection by considering whether there is demand for the service, how much it is used (for use values) or enjoyed (for nonuse values), and whether the particular site provides the access necessary for people to benefit from the service, among other considerations (Olander et al., 2015). BRIs are needed, because while carbon sequestration does not meet the definition of FEGS, it is categorized as a BRI because the research has been done to link carbon sequestration to benefits through the social cost of carbon and the climate.

Hence, from a conceptual perspective, all FEGS are BRIs, but not all BRIs are FEGS.

3.4 Compatible definitions?

The complexity of natural capital outputs and outcomes is complicated by multiple systems of measuring, accounting, valuing, and *defining* ecosystem services. This mix of issues is a cause of the low and diffuse ecosystem service values as well as a reason for high and multiple transaction costs.

The four ecosystem service definitions highlight the disparity among social, academic, ecological, and economical stakeholders in addressing the varied scope and scale of natural capital outputs and outcomes. Each definition is valid in achieving it individual objectives. The MEA's approach considers ecosystem services as the flow of goods to be managed for the well-being of humanity. Brown et al. (2007) and Daily (1997) take a pragmatic approach in describing ecosystem goods and services in the same manner people are accustomed to exchange economic goods and services in day-to-day transactions. Luck et al. (2009) identify ecosystem services within a spatial component that supports associated economic values. Boyd and Banzhaf's FEGS description adopted by a group of EPA scientists identifies human consumption and direct use of ecosystem services as the criteria to account for its economic value within broader economic indicators such as GDP.

Each of the motives of defining ecosystem services is valid and should be considered. In aggregate, they address human use issues, are aligned with typical transactions, and are spatially based and relevant within the broader economic system. Ultimately each of these attributes needs to be incorporated into the definition or the process of accounting for natural capital outputs to allow for measurement, ownership, valuation, and transactions to occur in a *compatible* manner. Compatibility, rather than a uniform or identical accounting and valuation process, seems to be more realistic due to the increasing number of disparate stakeholders participating in defining agriculture sustainability.