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Provision of Ecosystem Services through Market-Based Approaches

Department of Defense Applications

Elizabeth Keysar and William D. Goran

March 2008

Construction Engineering Research Laboratory

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Final Report

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Abstract: Military installations face increasing competition for important natural resources that provide ecosystem services not captured by current economic methods of valuation. Ecosystems naturally assimilate waste, attenuate noise, form soil, control erosion, regulate surface water flow, and buffer installations from surrounding communities. These services mitigate environmental impacts of training, help installations comply with environmental regulations, and ultimately enable the Department of Defense (DoD) to conduct training on installation lands. When undeveloped or rural land is converted to urban uses, valuable ecosystem services are lost. Accounting methods are needed to track the quantity and quality of ecosystem services and to inform decisionmaking such that needed services continue to be available. Market-based approaches can estimate the dollar value of ecosystem services and create financial incentives or markets for their valuation and trade. The DoD has recently begun to use these concepts in its policies and at its installations. This report investigates how to provide ecosystem services through market-based approaches. While there are significant institutional barriers, the authors concluded that market-based approaches can help ensure the continued supply of these services if these problems associated with monetizing ecosystem services, defining ecosystem production functions, and devising incentives can be resolved.

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Foreword

Over the past several years, numerous studies have highlighted the need to articulate, understand and quantify the benefits that humans derive from ecosystems. These benefits are critical to human health and the health of our planet. But because human benefits from ecosystems have been taken for granted, seemed plentiful, and have not been well understood or articulated, they have been omitted from our economic exchanges except in the case of goods that we extract, such as timber and crops. Humans use a wide range of ecosystem services — but we have only accounted for a small fraction of these ecosystem services in our economic exchanges.

As global population rises and the ecosystem service use 'footprint' rises for many members of our growing global population, human pressures on these services keep accelerating. Ecosystem service capacities have been rapidly dwindling in both extent and quality. Forests and prairies give way to farms, and farms give way to cities. Water flows to waterways and aquifers are impeded, habitat is lost or compromised, and the natural water and air quality filters of trees and grasslands are replaced by vehicles, factories, and buildings that emit contaminants. Few of there transformations involve any human recovered 'cost' for the reduction or loss of ecosystem services.

How does this impact the military? The military consumes ecosystem services when training for combat operations, when building and testing weapons, when conducting combat operations, when transferring troops and equipment around the globe, and when acquiring materials. Generally, these activities do not adequately account for ecosystem service costs. The military also has protected ecosystem services in many locations, because land used for training and testing missions has been 'held back' from transformations to commercial forestry, cropland, or urban uses and because it has been managed to preserve ecosystem values.

In 2004, the Army published a new Environmental Strategy that called on the Army to conduct all operations with benefits across the 'triple bottom line' of mission, community, and environment.

Then, in October 2006, the U.S. Army Corps of Engineers, Engineer Research and Development Center established a new capability to help the

Army achieve the vision articulated in their *Strategy for the Environment*. This capability is the Center for the Advancement of Sustainability Innovations (CASI). One of the first topics addressed by CASI was for the Director (William D. Goran) to draft a white paper (20 October 2006) on *Ecosystem Services — Exploring Their Potential Importance to the U.S. Military*. This whitepaper was not published, but was instead used as a background document by the Army Environmental Policy Institute (AEPI 2006).

AEPI established a process, called Foresight, to identify and articulate emerging sustainability issues, as part of the *2004 Army Strategy for the Environment*. AEPI holds Foresight forums to identify and address emerging topics, and also publishes bulletins to raise awareness, in the Army and across the other services, about these topics. In 2007, AEPI published a Foresight Bulletin entitled *Emerging Ecosystem Services and Markets*. Subsequently, in May 2007, AEPI sponsored a session of talks at the 2007 Joint Services Environmental Management (JSEM) conference, to provide an additional forum for discussion of Foresight topics. At this forum, William Goran gave a presentation entitled "Emerging Ecosystem Services and Environmental Banking — Opportunities for the Military."

The white paper and the Foresight bulletin only 'skimmed the surface' of the issues of ecosystem services and their military relevance. Because this issue will be of growing importance over the next few years, for society in general and for the U.S. military, the CASI Director decided to proceed with a more in-depth report on this topic. This special report is a response to this concern. This report provides background on ecosystem services and their emerging markets, and examines the programs and projects that are beginning to relate to these service concepts and markets, and also examining the institutional barriers to working with emerging markets.

Hopefully, this report, along with other efforts, will help engage the Department of Defense soldiers, civilians, and other stakeholders in creative discussions about how best to incorporate ecosystem service impacts into military decisionmaking, and how such decisionmaking can enhance the triple bottom line of mission, environment, and community.

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Preface

This study was conducted for the U.S. Army Corps of Engineers, Engineer Research and Development Center (ERDC), Center for the Advancement of Sustainability Innovations (CASI). CASI was established by ERDC, in October 2006, to help enable the U.S. military to proactively respond to current and emerging sustainability challenges. Ecosystem services are one of the CASI technology focus areas.

This work was conducted under ERDC Contract/Purchase Order No. W9132T-07-P-0113 by Concurrent Technologies Corporation. The technical monitor for this contract was Alan Anderson, Chief, Ecosystem Processes Branch (CN-N), of the Installations Division (CN), of the Construction Engineering Research Laboratory (CERL).

Appreciation is owed to the following individuals for their technical review of this work: John Fittipaldi, Army Environmental Policy Institute (AEPI), and Dr. Harold Balbach and Dr. Timothy Hayden, CERL Ecosystem Processes Branch (CN-N). The Director of ERDC-CERL is Dr. Ilker R. Adiguzel.

CERL is an element of the U.S. Army Engineer Research and Development Center (ERDC), U.S. Army Corps of Engineers. The Commander and Executive Director of ERDC is COL Richard B. Jenkins, and the Director of ERDC is Dr. James R. Houston.

Unit Conversion Factors

Multiply	By	To Obtain
acres	4,046.873	square meters
British thermal units (International Table)	1,055.056	joules
cubic feet	0.02831685	cubic meters
cubic inches	1.6387064 E-05	cubic meters
cubic yards	0.7645549	cubic meters
degrees (angle)	0.01745329	radians
degrees Fahrenheit	(F-32)/1.8	degrees Celsius
feet	0.3048	meters
gallons (U.S. liquid)	3.785412 E-03	cubic meters
inches	0.0254	meters
inch-pounds (force)	0.1129848	newton meters
miles (U.S. statute)	1,609.347	meters
square feet	0.09290304	square meters
square inches	6.4516 E-04	square meters
square miles	2.589998 E+06	square meters
square yards	0.8361274	square meters
yards	0.9144	meters

1 Introduction

Background

Military installations face increasing competition with surrounding communities for important natural and manmade resources in their vicinity. These resources include access to transportation systems, airspace, landfills, open space, wetlands, and fresh water. Growing populations around installations have resource needs that often overlap those of the installations. Growing populations impact land use as they convert undeveloped natural and rural areas into developed residential, commercial, and industrial uses to meet built infrastructure needs. Converting land from natural, to rural, to urban causes the loss of important 'natural infrastructure.'

As the Department of Defense (DoD) seeks to ensure the long-term viability of its operations, it must assess the availability of both manmade (built) infrastructure and natural infrastructure. It must do this inside the fence line, outside the fence line, and for the surrounding region. Strategies will be needed to address current and future shortages of important resources. This study was undertaken to examine those natural resources that present the most difficult policy and planning challenges: *to quantify benefits derived from ecosystems that are not captured by current economic methods of valuation*, referred to here as '*ecosystem services*.'

Economic benefits derived from ecosystem services are significant, as the following cases of New Jersey and New York City demonstrate. Lawmakers in the state of New Jersey recently passed legislation aimed at enhancing protection for the State's coastal resources. The January 2008 legislation forms a "New Jersey Coastal and Ocean Protection Council" with the mandate to prevent depletion of marine resources by adopting ecosystem-based management approaches. The declining health of the State's tidal rivers, estuaries, and bays has elevated this level of concern in large part due to the economic contribution these natural resources represent to the State. Tourism on the Jersey shore represents a $16 billion annual industry, and commercial fishing industries are worth $143 million annually (ENS 2008). Yet these economic contributions from the State's coastal ecosystems represent only a portion of the full value of healthy coastal ecosystems. They also provide flood control, regulate the flow of surface runoff, neutralize pollution, assimilate waste, and support biodiversity. No dollar values represent these services on balance sheet, yet in this case, the

markets for traditional goods and services (e.g., fisheries, tourism, and coastal real estate markets) are strong enough to get the attention of lawmakers. In many other ecosystems, the case for ecosystem protection cannot be made based on traditional markets, but the need for enhanced protection is just as pressing.

Another good example is the case of New York City's watershed protection, where ecosystem services related to pollution neutralization and waste assimilation have, in fact, entered the balance sheet. Land use surrounding the upstate reservoirs for the City was rapidly changing. As a result, the ecosystem services that naturally cleanse the City's water supply were decreasing. The City faced construction of a water treatment and filtration plant estimated at $6-8 billion. To ensure the continued supply of these ecosystem services, the City has developed a program in conjunction with the cities and counties of the watershed. The program includes buying land, constructing new storm sewers and septic systems, and providing pollution prevention assistance to farmers in the watershed; the program has a $1.5 billion price tag (Daily and Ellison 2002, p 63).

The dollar values associated with existing markets for ecosystem commodities from the rural land in New York City's watershed (e.g., tourism, farming and lumber) were not needed to make the case for improved ecosystem management and protection, but they represent additional values that belong on the balance sheet. In many other ecosystems, the case for ecosystem service protection cannot be made because the providers of the service and the beneficiaries are not so clearly evident, even though this relationship exists and the need for enhanced protection is just as pressing. However, in this case, the providers of the ecosystem services (upstate land owners) and the recipients (city residents) were clearly evident. The bottom line: this ecosystem service, which supplies clean water to 9.5 million people, is valued at more than $6 billion.

Another case, of U.S. Army Fort Benning, GA, is complicated both by inadequate valuing of ecosystem services and linking services providers to the beneficiaries. First, many of the ecosystem services needed to support training at this installation are not traded in existing markets, and are therefore not valued in dollars. As economic theory explains, this leads to the under-provision of these services. Second, there is no clear delineation of the source of the services (the ecosystem service providers) even though the recipient of the benefits (the Army installation) is clear.

Many of the ecosystem goods and services that Fort Benning requires are maintained on the installation itself, such as healthy and resilient vegetation for realistic training. Others can be purchased as commodities, such as clean water for potable water consumption. However, the installation requires ecosystem processes and functions that are not available within the fence line and are not accounted for by existing markets, such as airspace for training flights and clean air for waste assimilation. Other ecosystem processes and functions are needed to mitigate impacts related to training, which include buffers for incompatible development, wetland acreage, and habitat for endangered species. Although the installation has these requirements for ecosystem services, describing, quantifying, and assigning a dollar value to ensure their provision is a challenge. As a result, these services are often accounted inaccurately, or not at all. Often services that are public goods (such as air quality) by their nature cannot be traded. Other services could be traded (in theory), but there are no markets established to link the user (Fort Benning) with service providers, such as landowners with endangered species habitat.

Effective accounting methods are needed to track the quantity and quality of ecosystem services required to meet environmental and operational objectives in the DoD. Furthermore, policy instruments are needed to ensure the continued supply of these services. Market-based approaches account for ecosystem services by estimating the dollar value, creating financial incentives, or explicitly creating markets for their valuation and trade. Although the DoD has just begun to use these concepts in its policies and at its installations, these approaches need further exploration and validation for DoD applications.

Objective

The objective of this work was to examine the issues surrounding provision of ecosystem services through market-based mechanisms, specifically focusing on the application of these methods to support improved environmental and operational outcomes for the DoD.

Approach

Information to accomplish this research was drawn from a literature review, interviews with DoD subject matter experts (SMEs), and a class on the implementation of Transfer of Development Rights (TDRs).

The results of the research are organized into three main areas:

1. The concept of ecosystem services is detailed to define these services and to analyze and describe how they relate to DoD environmental and operational outcomes (Chapter 2).
2. Various market-based approaches that can provide ecosystem services are identified and explained (Chapters 3, 4, and 5).
3. Current and emerging applications of market-based approaches in the DoD are identified and described (Chapter 6).

The report concludes with recommendations for future actions by the DoD including policy development and ecosystem service pilot projects.

2 Ecosystem Services

Defining Ecosystem Services

An 'ecosystem' can be defined as the complex of organisms that appear together in a given area and their associated abiotic environment, all interacting through the flow of energy to build biotic structure and materials cycles (Ruhl et al. 2007, p 15). Ecosystems have a structure based on these interacting elements, and resulting processes that reflect the movement and transformation of energy. Ecosystem structure "refers to both the *composition* of the ecosystem and the physical and biological *organization* defining how those parts are organized" (NRC 2005, ES p 1, emphasis added), such as the vegetation and wildlife; the soil and water. Ecosystem function "describes a *process* that takes place in an ecosystem as a result of the interactions of the plants, animals and others organisms in the ecosystem with each other or their environment" (NRC 2005, ES p 1). Examples of ecosystem processes and functions (Ruhl et al. 2007, p 15) include:

- photosynthesis
- plant nutrient uptake
- microbial respiration
- nitrification
- plant transpiration
- root activity
- mineral weathering
- vegetative succession
- predator-prey interactions
- decomposition.

Both the structure and functions of ecosystems provide benefits to people. Military installations need ecosystem structures such as land, soil, streams and vegetation to support training. They also need ecosystem functions such as waste absorption, erosion control, photosynthesis, and decomposition to maintain the structure and to absorb impacts. Ecosystem structure and function do not become 'benefits' until someone uses them and they place a value on them; at this point they become 'ecosystem commodities and services.' The concept of an 'ecosystem service' is anthropocentric – it is about the benefits humans obtain from the natural world. Ecosystem benefits have conventionally been divided into three main categories (Ruhl et al. 2007, p 23):

1. Direct commodity consumption benefits
2. Direct aesthetic and recreational use benefits
3. Nonuse and other indirect existence benefits.

The first category represents direct benefits such as trees turned into paper, or grain used as feed to produce beef, or water for drinking. The end product, or commodity, is produced, bought, sold and consumed in capital markets. The underlying structure and functions for producing the commodity are found in the ecosystem. In American society, this includes the land itself – the most basic ecosystem structure – upon which homes, schools, roads, and industries are built.

The second category represents the aesthetic or recreational benefits that we hold for natural places, for sightseeing, hunting, wildlife viewing, or water skiing, which are also benefits that have a direct use character. The direct use nature of these structures and functions means that these benefits can be valued in dollars, such as the value placed on the New Jersey shoreline based on its ability to attract tourism. The final category includes the cultural and spiritual values people place on knowing that the resource exists. Non-market valuation methods are used to estimate the dollar values based on the fact that people want the Grand Canyon to be preserved, even if they never actually go there, i.e., 'contingent valuation' (Carson 2000). The non-use benefits of 'existence' can also be estimated in dollars because homes next to green space have a higher value than similar homes without green space i.e., 'hedonic pricing' (Farber et al. 2002).

Figure 1 shows how ecosystem structure and function translate into goods and services, which then are valued though economic methods. Human actions affect the condition (structure and function) of ecosystems and thus the ability to produce the resulting goods and services. For instance, clear-cutting a forest greatly impacts the land's ability to produce this commodity (lumber) for many years, and also impacts other services, such as the ecosystem's ability to provide surface runoff control and habitat.

Figure 2 shows some of the basic commodities and services provided by ecosystems that represent consumption, aesthetic, recreational, and non-use benefits, and how they relate to the underlying value of the land. Figure 3 shows the progressive changes as land converts from natural forest ecosystems to monoculture forest for silviculture, to other agriculture uses, and finally to developed land uses. The size of the text reflects the relative value of the good or service *including the value of the land itself*. The brown line in Figure 3 represents the typical increase in these marketable values as the property is developed.

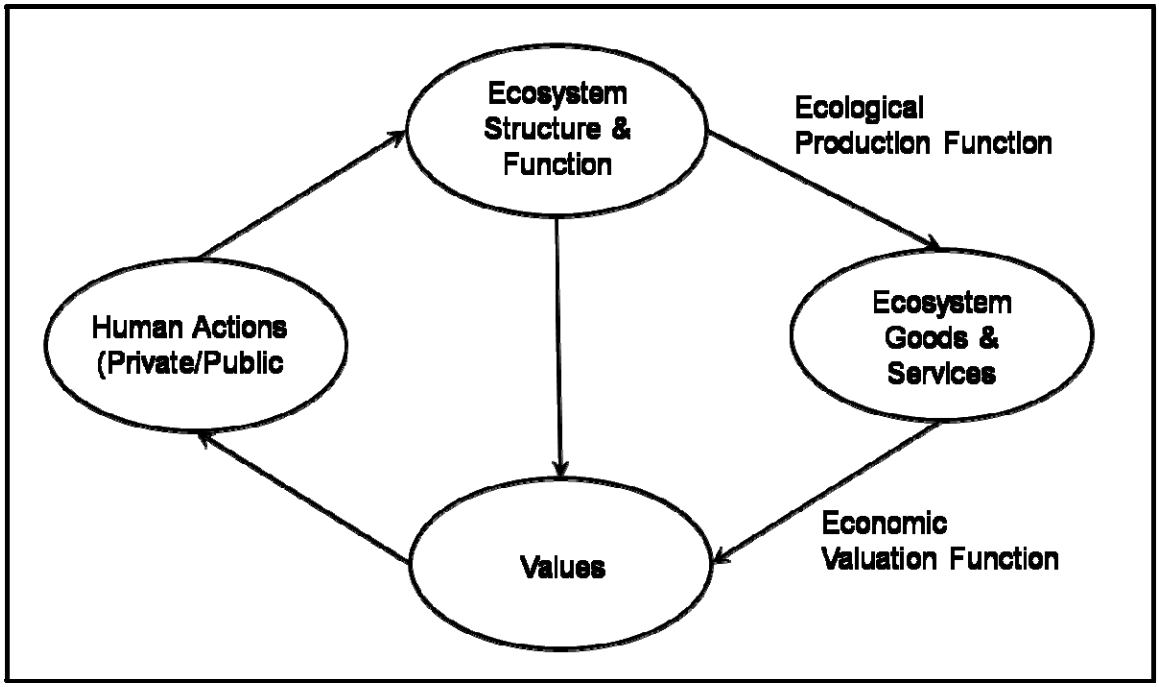

Figure 1. Components of ecosystem valuation (Source: NRC 2005, ES p 4).

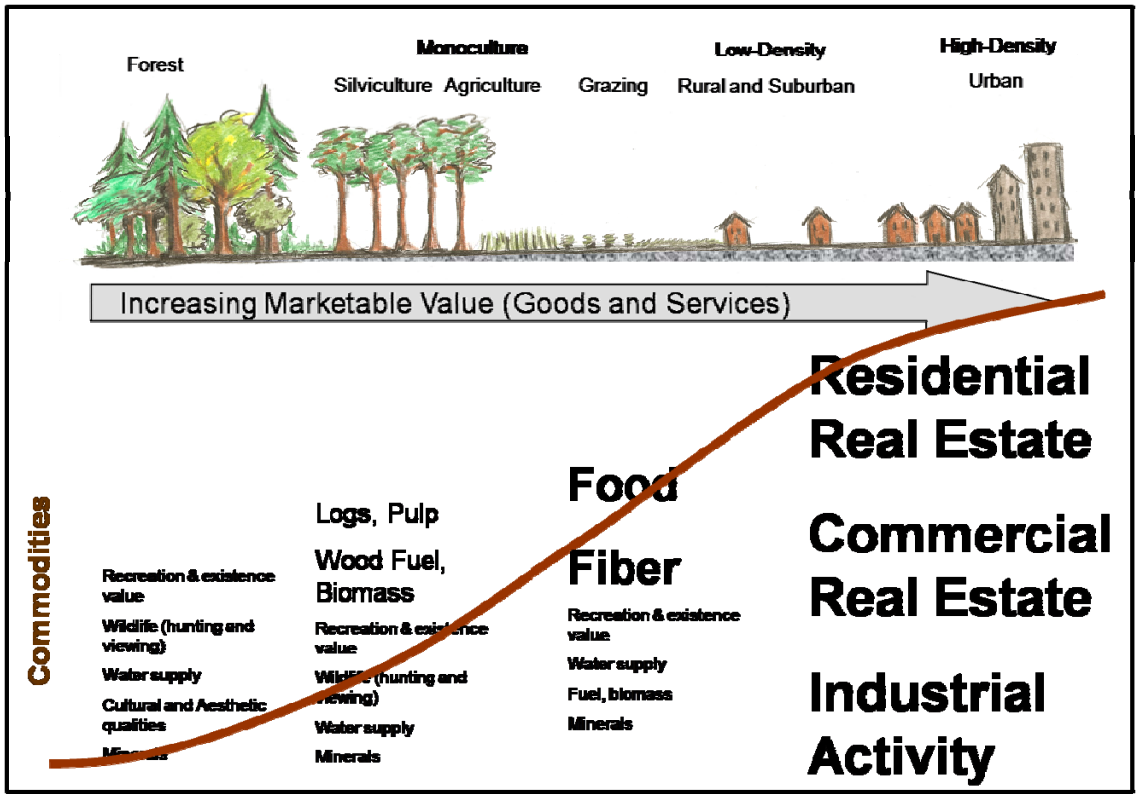

Figure 2. Ecosystem commodities and changes in land use.

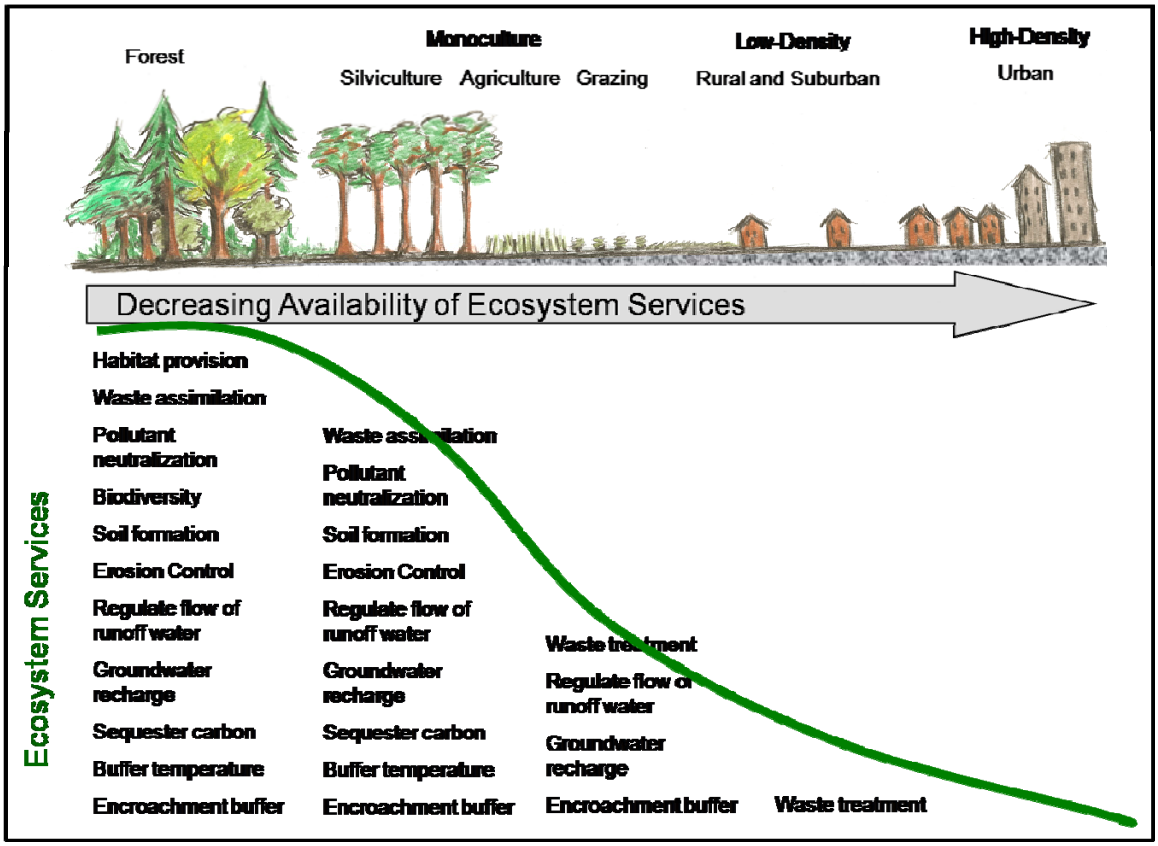

Figure 3. Ecosystem services and changes in land use.

This work focuses on a fourth category of ecosystem-derived benefits, commonly referred to as ecosystem services. These are the underlying services that people use, either directly or indirectly, but that have not been captured in the conventional economic valuation categories. There is a great deal of literature on these services; they can be described as the 'enabling and sustaining' functions and processes of ecosystems. The Millennium Ecosystem Assessment (MEA 2005) has categorized ecosystem services as: provisioning, regulating, cultural, and supporting. Table 1 lists the MEA breakdown. Ecosystem services are used indirectly to support the provision of natural commodities. Trees for lumber (and military training) depend on soil formation and nutrient cycling to grow. These services also provide direct beneficial use to humans, such as erosion control, pollination, flood control, and climate regulation. These services represent the fundamental, underlying functions and processes on which human economies depend, but which have not yet been effectively captured in economic terms.

Table 1. Ecosystem services (Millennium Ecosystem Assessment 2005).

Provisioning	Regulating	Cultural	Supporting
Food (crops, livestock, fisheries, etc.) Fiber (timber, cotton, etc.) Genetic (biochemicals, medicines, etc.) Fresh Water	Air Quality Climate Water *(flooding, runoff, aquifer recharge)* Erosion Water purification Waste Treatment Disease Pest Pollination Natural Hazard	Cultural Diversity Spiritual and Religious Values Knowledge Educational Values Inspiration Aesthetic Values Social relations Sense of place Cultural Heritage Recreation and Ecotourism	Soil Formation Primary Production *(photosynthesis)* Nutrient Cycling Water Cycling

Figure 3 shows some of the ecosystem services that are available from various land uses and illustrates how many services are lost as land use changes. “Conversion of land from its natural state to human use, or degradation of land from human use, is a primary reason for the loss of ecosystem services” (Krautkraemer 2005, p 31). This figure represents land converting from natural forest ecosystems to monoculture forest for silviculture, to other agriculture uses, and finally to developed land uses (the same transitions depicted in Figure 2). The green line in Figure 3 roughly represents the decreasing availability of ecosystem services.

Relevance of Ecosystem Services to the DoD

Ecosystem services are relevant to the DoD because it is a beneficiary of ecosystem structure and function, just as is the rest of the U.S. economy. DoD relies on ecosystem services to conduct training such as waste assimilation (for pollutant discharges), noise attenuation, soil formation, primary production, erosion control, regulation of surface water flow, and encroachment buffering. The DoD also needs ecosystem services to mitigate the environmental impact of its actions and comply with environmental regulations, such as wetlands mitigation and protection of endangered species. Installations have established natural resource and training land management programs to monitor and maintain on-post ecosystem structure and function. Issues related to off-post resources and associated constraints are referred to by the DoD as ‘encroachment.’ Encroachment issues (to a large degree) reflect the trends shown in Figure 3; as land use changes, ecosystem services decrease.

The Senior Readiness Oversight Council (SROC) convened in 2000 and outlined the encroachment pressures on DoD test and training ranges. Annual reports to Congress detail the status and extent of these pressures as well as the actions that DoD and the Services are taking to reduce them. The *2006 Sustainable Ranges Report* noted:

> [R]esidential, commercial, and industrial development continues to expand around once-remote military training installations. As a result, there are ever increasing limitations and restrictions on land, water, and airspace needed for military readiness activities ... (DoD 2006, p 1-2).

These limitations reflect resource scarcities, much of which can be tied to changing land use and the loss of underlying ecosystem services with "root causes [of] population growth and urban sprawl" (DoD 2006, p 9-4). Existing encroachment mitigation measures, such as Joint Land Use Studies (JLUS) and Army Compatible Use Buffers (ACUB) attempt to avert external encroachment pressures, but more effective strategies are needed to preserve natural and working lands both near installations and in the surrounding regions. The Air Force portion of the *2006 Sustainable Ranges Report* (DoD 2006, p 9-11) notes that:

> Though the historical approach of responding to regulatory requirements and community encroachment issues has been adequate to maintain the requisites operational training capabilities, it is becoming unsustainable for the long term. Air and water regulations, water supply, competition for frequency spectrum, and uncontrolled development near military installations require a management approach that assesses natural infrastructure assets from a perspective that is regional and cross media...The media are interconnected and the availability of the natural infrastructure for military training is significantly affected by activity throughout the region.

The ecosystem services provided by land *on* DoD installations, *adjacent* to DoD installations and within the surrounding *regions* are of value to the DoD, but the characteristics of the services and the general lack of inclusion in decisionmaking has meant they are not adequately provided, or in this case, preserved. As noted by the National Academies of Science, "Failure to include some measure of ecosystems services in benefit-cost calculations will implicitly assign them a value of zero" (NRC 2005, ES p 5).

Figures 2 and 3 illustrate a fundamental issue of ecosystem service provision; land that provides the *most* ecosystem services is valued the *lowest* in economic terms. Lands that have been protected are "historically low in economic value, or lands provided by individuals with a strong conservation ethic" (Bruggeman et al. 2005, p 531). In other words, land conservation and protection has mostly been opportunistic. Environmental and operational outcomes are therefore not maximized. Likewise, "rates of land conversion from habitat to development increase with economic value of the land" (Bruggeman et al. 2005, p 518), so this becomes a race against time as the U.S. population continues to grow and land development continues to 'sprawl.' More effective means are needed to justify the protection of real estate that may be valuable in the traditional market, but also has significant value in environmental and military terms. Methods that identify, describe, quantify, and value ecosystem services help raise the value of the land that generates the ecosystem services. Valuation methods are needed so that landowners have more economic incentive to keep their land in natural or rural conditions.

The DoD attempts to ensure compatible land use though land use controls (e.g., zoning regulations) and with the purchase of development rights (e.g., conservation easements). Both of these methods are effective, but cannot meet increasing scarcities, especially those that are regional in nature. Land uses that are supportive of and/or compatible to military training need to have this value reflected in the market price. The red line in Figure 4 represents the potential *combination* of ecosystem commodities and services. If the price of land incorporates *all* of the environmental, operational, and economic value represented by that land use, then the total value will, in fact, be accurate (or at least more so) and land-use decisions will not follow a pre-determined path as they tend to now. Successful operational and environmental outcomes over the long term depend on such a complete valuation process.

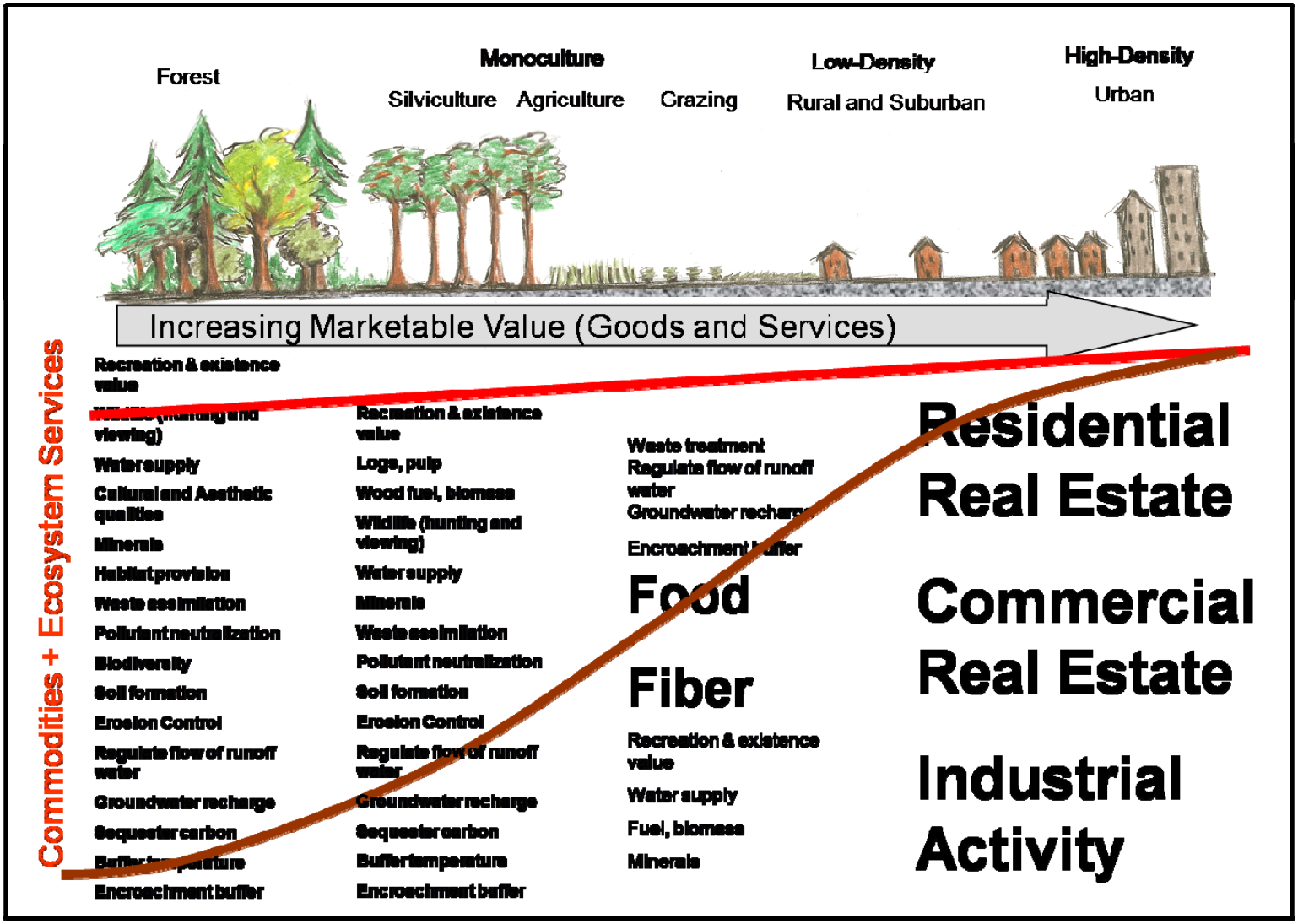

Figure 4. Ecosystem commodities and services combined.

3 Market-Based Approaches

The fundamental issue with ecosystem services is that they are not valued in conventional economic terms, and thus they are often under-provided. A relevant example for the military is the loss of endangered species habitat in regions containing military installations. As land is converted to agriculture or developed uses, many ecosystem services are lost such as the provision of habitat for endangered species (i.e., maintenance of biodiversity). There is no dollar value for 'acres of habitat' that a landowner can benefit from, so there is a lack of incentives to keep land in a natural state. Greater financial returns are accrued for the landowner in developed uses (refer to Figure 2); therefore this ecosystem service is underprovided. Economic theory helps explain this problem:

> The resource management problem is not that the owner of the natural capital cannot exclude others from access, but that...the benefits of the resource stock are positive externalities the owner cannot capture as value in the market. In other words, the beneficiaries of ecosystem services do not overconsume them; rather, the owners of natural capital undersupply them. (Ruhl et al. 2007, p 165)

To address this fundamental issue of economic value, market-based approaches are often proposed to redress ecosystem service resource problems.

Market-based approaches can be defined generally as methods that "affect estimates of costs of alternative actions open to economic agents" (OECD 1994, p 7). Market-based approaches typically use regulation or government-based programs to adjust market prices to incorporate positive or negative externalities. More specifically, market-based instruments are "regulations that encourage behavior through market signals rather than through explicit directives regarding pollution control levels or methods" (Stavins 1998, p 1). "The essence of [a] market-based instrument ...is that the policy measure sets a price or a quantity, but leaves the resource user or polluter to respond in a manner largely of their own choice" (Pearce 2005, p 202).

Many market-based approaches have been applied to the provision of ecosystem services, although implementation challenges limit success and more widespread application. This chapter uses several examples of these approaches to demonstrate the range of available options. Table 2 lists these approaches. This chapter closes with a review of general benefits and challenges to implementing these approaches.

Table 2. Market-based approaches.

Method	Example	Reference
Subsidies Tax Relief	Paying farmers to enhance provision of ecosystem services	Conservation Reserve Program rental payments (Ruhl et al. 2007)
Taxes and Fees	Impact Fees, Impact Taxes	Growth management technique to address impacts associated with new development (Nelson and Duncan, 1995)
Financial Incentives	Payments to buy newer cars, remove old cars	Texas "Drive a Clean Machine" program (ENS, 2008b)
Acquisition of Development Rights	Transfer of Development Rights (TDR) Purchase of Development Rights (PDR) Conservation Easements	Purchase of Agricultural Conservation Easements (PACE) – pay agricultural landowners to restrict their land from future non-farm development (American Farmland Trust, 2006) TDR – Land use regulation allowing developers to increase density in receiving area by reducing development rights in sending area (Pruetz, 2007)
Establish an Explicit Market (cap-and-trade)	SO_2 emission trading under Clean Air Act	Cap on total sulfur dioxide emissions from coal-fired power plants with allowance trading at national scale (Ruhl et al. 2007)
	Nitrogen and Phosphorous pollution trading under Clean Water Act	Water pollution trading districts within a single watershed (Ruhl et al. 2007)
	Carbon trading under Kyoto Protocol	Global market to reduce carbon in the atmosphere (Ruhl et al. 2007)
Mitigation Off-Sets	Wetland mitigation bank under Section 404(a) of the Clean Water Act	Offset adverse impacts of development actions, or other actions that impact wetlands (Ruhl et al. 2007)
	Conservation banks under Endangered Species Act	Land managed as nature preserves in perpetuity - Carlsbad Highlands Conservation Bank, CA (Bayon, 2002)
	Carbon off-sets	Techniques to mitigation carbon emissions (Gillenwater et al., 2007)
Direct Payments	Direct payment to Ranchers in Florida	Florida Ranchlands Environmental Services Project: Field Test (Lynch and Shabman, 2007)
	Direct payments protect biodiversity	Costa Rica pays rural residents to protect forests (Ferraro and Kiss, 2002)

Subsidies and Tax Relief

Subsidies and tax relief are government-funded programs designed to create positive incentives and alter behavior. Subsides are typically "economic payments in the form of cash or avoided costs such as reduced fees or taxes" (Ruhl et al. 2007, p 276). Agriculture is one sector where subsidies are commonly used and "after decades of doling out income support subsidies that actually promoted...harmful use of the environment, our farm policy is shifting toward greater use of 'green' subsidies to induce farmers to take high-value natural capital out of production" (Ruhl et al. 2007, p 276). Under the 20-year old Conservation Reserve Program (CRP) rental payments are made to farmers when they remove highly erodible and marginal farmland from production. The Federal government 'rents' the landowners' 'cropping rights' through 10- and 15-year contracts.

Over time the program has expanded to include other ecosystem services in addition to erosion control from lands that are included in the CRP. An Environmental Benefit Index (EBI) is constructed for the bidding process; winning bids have the highest EBI. Points are given for: wildlife cover; water quality benefits (reduced erosion, runoff and leaching); potential for land to erode; enduring benefits (likelihood conservation benefits will remain after CRP contract expires); air quality benefits from reduced wind erosion, and carbon sequestration. According to Ruhl et al. (2007, p 191):

> Since its inception in 1985, the CRP has been modified from a program dealing primarily with soil erosion to one of the nation's premier programs retiring agricultural lands from production while protecting and enhancing the flow of diverse ecosystem services from working agricultural landscapes.

There are moral hazard concerns with subsidies in that they may lead to potential beneficiaries engaging in the 'wrong' behavior so they can be paid to 'correct' it. Federal funding for subsidies is also subject to variation from year to year based on funding priorities. There are also challenges in monitoring after the payment to ensure the 'subsidized' behavior is occurring and social benefits are accrued. There is potential for expanding this type of 'government rental' approach to land other than agricultural as described in the section below on "Direct Payments for Ecosystem Services." As Ruhl et al. (2007, p 277) point out:

> If property rights would allow a landowner to deplete wetland resources that it would otherwise be more efficient in terms of overall social welfare to conserve, it should not matter to society whether the person to whom it is paying the subsidy is a farmer or a shopping mall developer.

Taxes and Fees

Taxes and fees work to influence behavior, but unlike subsidies and tax relief, these are negative incentives — 'sticks' to subsidies' 'carrots' (Ruhl et al. 2007, p 277). Although these government mechanisms may work to address ecosystem service scarcities, there are few applicable examples. Politicians are reluctant to institute new taxes due to the negative attention they receive. Impact fees and impact taxes are commonly used by local communities to help manage development pressures. High-growth communities in particular have a hard time keeping up with needed infrastructure; roads, schools, police stations, fire departments, etc. Impact fees are assessed on new development to help meet these off-site capital improvements. They can be used as a growth management technique to direct development to areas with existing infrastructure (areas where fees are less). "Impact fees are a conservative response to the notion that development should pay its own way" (Nelson and Duncan 1995, p 122); therefore, it is conceivable that development impacts to ecosystem services could be captured with this growth management tool. However, impact fees have yet to be used in this manner.

Financial Incentives

Other unique and innovative uses of financial incentives can be found as state and local governments address environmental issues. Clean air is a classic example of an ecosystem services with public good qualities. There is no way to stop one person from 'using' this resource – even though the individual's use may reduce the availability of the resource for everyone else. This ecosystem service – cleaning air through waste absorption of gaseous pollution – is typically plentiful and free of charge. The major air polluters (e.g., power plants) have been taxed and regulated in an attempt to 'charge' them for their use of this public good (i.e., internalize the negative externalities of their activities).

Taxing and regulation have only addressed major point sources, and pollution of the air has reached critical levels in large, automobile-dependent

cities such as Dallas and Houston, TX. These cities are non-attainment for U.S. Environmental Protection Agency (USEPA) criteria pollutants; which is an indication that the ecosystem service is being overused as a result of it being underpriced. An innovative method is being used by the AirCheckTexas "Drive a Clean Machine" program to address the over-use of this resource. They are attempting to buy cleaner air by buying newer vehicles. A program funded by vehicle-inspection fees in the Dallas and Houston areas offers up to $3,500 towards the purchase of newer vehicles in an attempt to get older, polluting cars off the road. The Texas Commission on Environmental Quality (TCEQ) estimates that 20 percent of the vehicles in these metro regions are 10 years old or older. The TCEQ concludes that helping owners buy newer cars is an effective way to reduce pollution and represents a "good return on taxpayers' investment" (ENS 2008b).

Acquisition of Development Rights

Many ecosystem service challenges are related to land use; in particular, rapid changes in land use from natural and rural conditions to more developed uses. There are many existing growth management tools that are used to slow, direct and otherwise influence the character and pace of land development (Nelson and Duncan 1995). These approaches must be applied at the local level, since local governments have the authority to regulate land use based on police power granted in state constitutions (Juergensmeyer and Roberts 2003).

The ability to gain economic benefit by relinquishing development rights while retaining ownership is the basis of many conservation and farmland preservation programs. Private landowners are paid for a permanent conservation easement, or a development restriction, on their land. These legal tools are based on the concept that property ownership consists of a bundle of rights. These include the right to use, lease, sell, or bequeath the property; the right to develop the property; to borrow money against the property; or to exclude others from access or use. Other rights include water rights, mineral rights, air rights, and the right to farm. The ability to exercise these rights is not without restrictions, however. Land use zoning regulations, nuisance laws, and development codes impact choices available for any given parcel.

Traditional land use controls such as land use plans, zoning, and subdivision regulations are proving inadequate for preservation of ecosystem services (Calthorpe and Fulton 2001; Randolph 2004), so these tools are being supplemented. Purchase of Development Rights (PDR) and Transfer of Development Rights (TDR) are market-based mechanisms that attempt to separate some property rights while the owner continues to hold title to the land. These tools rely on existing zoning designations that must establish the development rights before they can be traded or purchased. Conservation easements are an important component of PDR/TDR schemes; they typically serve as the legal instrument for recording development restrictions placed on a piece of property. One example of PDR programs are Purchase of Agricultural Conservation Easements (PACE). These are used to pay agricultural landowners to restrict their land from future non-farm development (AFT 2006).

A TDR program involves the trading of development rights within a given geographical area, rather than just an outright purchase. A TDR program "allows increased development in places where a community wants more growth in return for reduced development where it wants less" (Pruetz 2007, p 3). A community establishes areas where higher density (such as a 'village center') is acceptable in an overall land use plan. This becomes a receiving area. Other areas where development is to be discouraged are the sending areas. These can include "environmentally sensitive places, farmland, historic landmarks, open space, or any other resources that a community wants to preserve" (Pruetz 2007, p 3).

All of these geographic designations are laid over existing zoning of a certain density for which landowners can continue to exercise as their 'development rights.' The land owners in the receiving areas must 'buy' development rights to increase their density (development potential) from land owners in the sending areas. The owners in areas of preservation thus gain the economic benefit of developing their property without actually doing so, and lose the right to develop beyond a new, lower density. TDR programs have been growing in number and scope over the past 40 years with varying levels of success. Rick Pruetz (2007) reports there are "181 TDR programs in 33 states that have preserved at least 300,000 acres of farmland, natural areas and open space" (p 3).

Establish an Explicit Market

Ecosystem services can be traded if a market exists. Economic theory predicts the efficient allocation of resources if perfectly competitive markets exist and transaction costs are low (Freeman 1983; Simon 1981). Governments frequently intervene in markets to ensure competition and low transaction costs. As Agrawal and Lemos (2007, p 43) note:

> The efficient performance of markets requires that a large number of conditions related to information, property rights, competition, externalities, transaction costs, and product characteristics to be satisfied ... The creation of new markets is neither trivial nor possible without strong and effective action by the state.

There are examples of governments explicitly creating a market for an environmental good or service. The motivation is to achieve desired environmental end points at a lower cost than traditional command and control regulatory approaches. These markets are created within a regulatory support structure; pollution cap and trade schemes are the most common examples.

In a typical cap and trade application, a regulatory body sets an overall cap on a given pollutant, such as the U.S. market in sulfur dioxide (SO_2), and then allocates baseline quantities of the substance to the producers. A market then emerges as producers determine the most cost-efficient way to meet their regulatory obligation. They can reduce their own emissions and sell the excess credits created, or they can purchase credits from others to avoid treatment or non-compliance costs. Of the various market-based approaches, these markets are the most amenable to trade because the geographic scale is large (which allows many buyers and sellers), and because the substance can be easily measured so that trade can be monitored and verified by regulatory agencies (Ruhl et al. 2007). The cap and trade concept has been modified and expanded from specific air pollutants in a single nation to a global trading for reduction of Greenhouse Gases (GHGs) (Gillenwater et al. 2007).

Recent developments in trading water quality pollutants within a watershed are also emerging with the adoption of a Water Quality Trading Policy by the USEPA (2003). Total Maximum Daily Loads (TMDLs) are pollution caps set for watersheds in accordance with the Clean Water Act. These

caps, along with the EPA's Water Quality Trading Policy appear to have set the stage for trade in water *quality*. This type of trade is different from water *quantity* trade, which already exists in the western United States. Although there have been many pilot studies in nutrient trading, the success of water quality trading is still unproven (Ruhl et al. 2007). The most commonly traded substances are nitrogen and phosphorous, and usually only a single pollutant is traded between point sources or between point and non-point sources, with the point source responsible for ensuring the reductions are met. Trades are often one-time only, and active markets have not yet developed (Breetz et al. 2004; Morgan and Wolverton 2005).

The water quality market is limited for several reasons (ETN 2003; Kieser and Fang 2005):

1. The spatial extent is a watershed, limiting the number of buyers and sellers.
2. The potential for 'hot spots' exists. (Pollutant levels are very high in an isolated area of the larger unit.)
3. Non-point sources are not regulated, lessening their motivation to trade.
4. Relative impacts of control mechanisms for non-point sources are not well documented.
5. Local regulatory agencies do not have the fiscal or professional capacity to develop and monitor these programs.

Analysts are optimistic that the early lessons learned will help to overcome these issues and to develop a market (Faeth 2000; Kieser and Fang 2005). Others see the spatial limitations of watershed trading that result in a lack of potential traders as a fatal flaw that is unlikely to be overcome (Ruhl et al. 2007).

Another important area of cap-and-trade policy is related to Greenhouse Gases (GHGs). Over the past decade, climate change has become recognized as a pressing international concern, with environmental sustainability, energy security, and national security implications. Local, state, national, and international climate change policy is changing rapidly. The primary focus of these policy changes is on managing GHGs emissions from human activities, which, according to atmospheric scientists, is increasing atmospheric GHG concentrations and contributing to climate change. Several Congressional bills are specifically aimed at reducing GHG

emissions. Local, state, and regional governments and partnerships are actively establishing GHG policy and programs aimed at reducing GHG emissions.

The USEPA's air pollutant cap and trade programs for reduction of volatile organic compounds (VOCs), carbon monoxide (CO), nitrogen oxides (NO_x) and sulfur dioxide (SO_2) served as a model for the United Nations as it developed policies to address climate change (Rosales 2004). Trading in greenhouse gases (GHGs) has been endorsed through the United Nations Framework Convention on Climate Change (UNFCC) and the resulting Kyoto Protocol. This Protocol set caps and reduction targets for each country. Each country can then implement policies to reduce emissions by major producers within their boundaries, specifically setting reduction targets and allowing producers to 'trade' in the emerging carbon markets. The broad spatial scope and international support makes GHG trading the "most ambitious tradable permit program to date and one of the most well developed" (Rosales 2004, p. 7). Similar to the USEPA cap and trade programs, each polluting entity can achieve the necessary reductions in the most economically efficient manner possible, either by trading with others who have excess credits, reducing emissions through new technologies, energy efficiency or renewable energy sources, or by investing in offset projects such as carbon sequestration. A global market in 'carbon transactions' now exists with two types of trade: allowance-based programs such as the European Union Emission Trading Scheme and the Chicago Climate Exchange, and project-based transactions for Certified Emissions Reductions (Capoor and Ambrosi 2006).

Mitigation Offsets

The offset concept attempts to place a value on an ecosystem service by mitigating the negative environmental impacts of development projects. The method typically employed requires development interests to 'pay' for the impacts of their projects, whether through on-site or off-site restoration, or by paying a fee to an entity that will contribute to conservation efforts (in-lieu-fee programs). These programs are most often part of a permitting process and the regulatory agency controls the costs, timing, and criteria for success, therefore they are generally not considered 'markets' (IUCN and Insight Investments 2004), even though they are market-based approaches. Conservation banking and wetland mitigation banking are

two offset based programs sponsored by the U.S. Fish and Wildlife Service (USFWS) and the USEPA, respectively (USFWS 2003; USEPA 1995).

The most recognized offset program is the wetland mitigation banking approach under Section 404 of the Clean Water Act. In this case, offsets are wetland credits established by restoration or permanent protection of a wetland at a different location than the filled wetland. The permit process requires anyone who is filling a wetland to establish compensatory mitigation, either on-site, off-site through a wetland bank, or through an in-lieu-fee program. Preference is given first to avoidance and on-site mitigation over off-site projects established further away.

Wetlands mitigation banking has been criticized for many reasons, the strongest of which is that, because mitigation is focused on 'no net loss' of acreage, many important functions and processes of wetlands are not successfully restored or preserved. Other concerns focus on the spatial shifting of benefits. Even if the ecological benefits are greater with a remote bank, the benefits to people (ecosystem services) have now moved from one set of recipients to another (Ruhl et al. 2007). Recent regulations proposed by the DoD and the USEPA will set procedures and criteria to improve the success rate of wetland offset techniques, indicating that this offset program will continue to have a role in protecting ecosystem services (DoD and USEPA 2006). The relative importance of wetland mitigation banks can be seen in the 'price signal' it sends to developers: "[those] who want to develop a site that has wetlands will spend considerably more per acre, so they had better be absolutely sure they must have that particular site" (Bayon 2008, p 129).

Conservation banking is the permanent preservation of privately or publicly owned lands managed for endangered or threatened species (USFWS 2003). The bank provides endangered species 'credits' to developers or land owners to mitigate damage to habitat or other unavoidable impacts. The sale of credits provides funding to buy land and conduct necessary management of the habitat. The creation of conservation banks is a relatively recent approach; since 1995, approximately 45 banks were approved, mostly limited to California (USFWS 2005). Examples of conservation banks include a bank for gopher tortoises in Alabama (Groutt 2005) a red-cockaded woodpecker (RCW) bank in Georgia (Environmental De-

fense 2003), and the Carlsbad Highlands bank in California for the coastal California gnatcatcher (Bayon 2002).

The concept of endangered species recovery credits has been adopted by the USFWS, and a *Recovery Crediting Guidance* has recently been developed and posted for public comment (USFWS 2007). The proposed guidance acknowledges that a recovery credit system is just one tool for recovery of species, and that the status of the target species must improve as a result of a credit trading scheme. The draft guidance states: "Federal agencies may obtain credit for conservation actions undertaken on non-Federal lands to advance the recovery of listed species, and this credit may be expended, or debited, to offset potential adverse effects of future actions" (USFWS 2007, p 62259). Although dollar values and a 'market' for these credits are not explicitly described, this document clearly sets the stage for private markets to develop.

Direct Payments

An example of economic incentives for the provision of ecosystem services that is relatively new is called "Payments for Ecosystem Services" (PES) (Agrawal and Lemos 2007; Lynch and Shabman 2007; Ferraro and Kiss 2002). PES is similar to agricultural subsidies in that it represents methods to supplement the income of landowners in reward for engaging in environmentally desirable actions. The difference is primarily in the explicit recognition that payments are for ecosystem services. Examples are few but growing. In Costa Rica, the government "pays rural residents about $35 annually per hectare of forest protected." These "direct payments benefit poor farmers by increasing cash flows, providing a fungible store of wealth, and diversifying sources of household income" (Ferraro and Kiss 2002, p 1719).

A field test of PES is currently being conducted in the Everglades region of Florida called the Florida Ranchlands Environmental Service Project (FRESP). There are many environmental quality problems in the Everglades region as a result of decades of water control projects, land use changes, and agricultural activities. This field test focuses on providing ecosystem services to improve water quality in Lake Okeechobee: water retention, phosphorus load reduction, and wetland habitat expansion. The collaborative effort was initiated after "a study concluded that the agencies

could buy these environmental services from cattle ranchers at a lower cost than producing the services by building public works projects" (Lynch and Shabman 2007, p 19). The program is currently developing measurement and accountability tools and working with the ranchland owners. The desired result is that "ranchers, who face low profit margins and fluctuation in the price of beef, will be provided with another source of income, creating a financial incentive for land to remain in ranching rather than be converted to more intensive agriculture and urban development — land uses that will further aggravate water flow, pollution and habitat problems" (Lynch and Shabman 2007, p 18). In other words, the Florida researchers and policy makers hope to stem the loss of ecosystem services provided by the rural land by making this land use competitive to more intensive use.

4 Benefits to Market-Based Approaches

Market-based approaches offer many benefits primarily because they can be used to assign economic value to ecosystem services and appropriately include them in decisionmaking and market activities. This chapter explores the benefits.

Continued Provision

One of the most important benefits of market-based approaches is ultimately their ability to ensure that ecosystem services are provided to those who need them, when they need them, for as long as they are needed. These methods attempt to promote the continued provision of ecosystems services by creating a 'price' for them. Market-based approaches provide an opportunity for land owners to generate additional income in a manner that also generates a public good. These services are of value to society, but may be underprovided due to the lack of market, or at least to the lack of an associated dollar value. In the case of habitat or undevelopable land due to wetlands or stream buffers, etc., these methods provide the opportunity to turn a liability into an asset (Bayon 2002; Finn et al. 2006). A successful market-based approach can give landowners a way to capture the value of their land in a natural or rural state, values that traditional markets do not capture. Decisionmakers would then have incentives to retain the land in less developed states, thus ensuring that the land can continue to provide needed ecosystem services.

Improved Decisionmaking

In a constrained resource environment, trade-offs must be made in the allocation of resources. A decision to site a new training range requires an evaluation of all potential locations and the costs and benefits associated with each location. All important values need to be included to make the best decision possible, given constraints on time and analytical capabilities. Identifying, quantifying, and valuing ecosystem services enables a more complete set of information to be used in decisionmaking. Typical cost-benefit analyses (CBA) do not include *all* costs and benefits, since

CBA focuses on the dollars that end up at the bottom line of the balance sheet. Many ecosystem goods and services do not have a price. Economic techniques that identify price (even if it is estimated) help ensure that these values are considered, and the final decision maximizes both operational and environmental outcomes and ensures long-term sustainability of the mission. As pointed out by Robert Costanza (1996 [quoted from Ruhl et al. 2007, p 31]):

> Ecosystem services are real. They have measureable value to humans, and whether we know their precise economic value or not, the fact that society has to choose how to allocate natural resources necessarily requires valuation of ecosystem services in some form or another.

Improved Environmental Compliance

Other benefits that result from successful market-based approaches are related to environmental compliance. These include increased flexibility, simplicity and predictability in meeting regulatory requirements for mitigation – potentially saving time and money. For conservation efforts (habitat, wetlands, farmland, etc.), it reduces the 'piecemeal approach' and allows for larger, more contiguous tracks of land to be preserved, thus improving environmental outcomes. In rural areas, it provides a way to support the traditional farming economy (AFT 2006). Conservation banks, wetland mitigation banks and recovery credits are all methods that "bring together financial resources, planning and scientific expertise" in collaborative fashion – allowing for economies of scale to be realized (USFWS 2003, p 2). Establishing a credit system can help reduce uncertainty in future land use decisions.

5 Challenges to Market-Based Approaches

There are many fundamental challenges in valuing ecosystems services and assuring their supply (NRC 2005; Tilman and Polasky 2005, p 79; Spash 1991). This chapter reviews some of these challenges and helps explain why one of the most difficult natural resource planning and policy issues is to ensure that ecosystem services will continue to be provided.

Estimating Nonmarket Values

The characteristics of ecosystem services make them difficult to describe in both quantitative and economic terms. Although economic valuation methods can be used to approximate the dollar values and set prices for ecosystem services, these are at best only imperfect estimates.

Understanding the Ecosystem Production Function

Ecosystems are complex. Even with advances in ecology and environmental economics, estimating the quantity and quality of goods and services produced as a result of ecosystem structure and function is imprecise. The links between ecosystem structure and function and resulting benefits are poorly understood. In the manufacturing sector, this relationship is called the 'production function'; certain amounts of raw materials and labor equal certain amounts of finished products. Ecologists are working to describe and measure ecosystem structure and function, but ecosystems have certain characteristics that make estimating the value of ecosystem services a practical and conceptual challenge (Spash 1999) because:

1. Ecosystem change is episodic rather than continuous and gradual.
2. Scaling up from small to large is a nonlinear process.
3. Ecosystems may exhibit multiple equilibria, or an absence of equilibria, and are destabilized by forces far from equilibria.

Devising Incentives

Ultimately, the behavior of market actors must be influenced to ensure the continued supply of ecosystem services. Government regulation, property rights, and social norms all influence behavior. These factors must be modified in a concerted fashion "that will lead those who make decisions affecting the supply of ecosystem services to maintain their supply" (Tilman and Polasky 2005, p 79). The 'public good' nature of many ecosystem services makes it difficult to exclude anyone from using them; "the costs of maintaining ecosystem services are typically borne by the landowners or other local decisionmakers, whereas the benefits typically accrue more broadly" (Tilman and Polasky 2005).

Developing Institutions

If the problems of monetizing ecosystem services, defining the ecosystem production functions, and devising incentives can be resolved, there remains the need for institutions and policy mechanisms that are "flexible, adaptive and experimental at scales compatible with those of critical ecosystem functions" (Spash 1999, p 427). This highlights another significant implementation problem. Bureaucratic institutions are rarely flexible or adaptive, and are seldom inclined to be experimental. Moreover, few effective regional institutions exist.

6 Department of Defense Applications

There are many examples within the DoD where benefits derived from ecosystems are delineated and assessed to ensure continued supply. Each of the examples of market-based approaches attempt to address *benefits derived from ecosystems that are not captured by current economic methods of valuation*. This chapter presents several examples of DoD applications based on the categories of actions described in the previous chapter (cf. Table 2, p 14). Most of these efforts are either limited in scope or in early phases of development. A common theme is that many market-based approaches require regulatory drivers, which take a great deal of time and effort to design and implement. They require solid scientific foundations and buy-in by stakeholders in the communities. Table 3 summarizes these examples.

Table 3. DoD examples of market-based approaches.

Method	Example	Reference
Financial Incentives	Environmental Credits	Air Force Natural Infrastructure Valuation
Mitigation Offsets	Wetland mitigation bank under Section 404(a) of the Clean Water Act Trading of Offsets	Fort Stewart Canoochee Creek Reservoir wetlands mitigation bank Camp Lejeune Sandy Run mitigation bank McGuire AFB air permit headroom
Acquisition of Development Rights	Conservation Easements	Fort Drum is evaluating ways it can use ACUB land for additional purposes
	Transfer of Development Rights (TDR)	MCAS Beaufort is developing a TDR program with neighboring communities to reduce development density on land adjacent to the installation
Establish an Explicit Market	Ecosystem credits	Fort Carson and the Colorado Short-grass Prairie Partnership: Developing viable units of ecosystem services for possible future trades
	Economic Development	Fort Bragg, BRAC RTF Regional Agricultural Sustainability Program

Financial Incentives

The first example of a DoD application of market-based approaches is that of the Air Force's Natural Infrastructure Management (NIM) framework. The Air Force has drafted policy and guidance for Natural Infrastructure Assessment (NIA) as part of its overall NIM framework. The Air Force is also developing NI Valuation as part of the overall NIM concept. Although these efforts have not reached a 'market' stage, the Air Force is making significant strides in the assessing and valuing portion of market-based approaches.

The concept of ecosystem services has been captured by the DoD as part of the 'natural infrastructure' (NI) needed to support the operational requirements of a military installation or training/testing range. The Air Force has developed a system of defining, quantifying, and valuing its NI assets, and has conducted Natural Infrastructure Assessments at several of its installations. The term 'infrastructure' is most commonly associated with the Built Infrastructure – civil infrastructure or public works – the system of roads; electric, telephone, and cable lines; potable water treatment and distribution systems; wastewater collection and treatment systems; and bridges, dams, and levees. Green infrastructure is also used to capture the ecosystem structural elements of communities to advocate active planning for the 'green' alongside the 'grey' (built). The DoD defines NI as (DUSD I&E 2006, p 34):

> ... the natural (such as land, water, air, space and frequency spectrum) and statutory assets (such as permits, credits, and other legal entitlements) at installations and ranges which, together with the operational components facilitate the conduct of the Defense mission.

This work defines ecosystem services as a subset of natural infrastructure: those natural resources that present the most difficult policy and planning challenges because the benefits derived are not captured by current economic methods of valuation. The listing in Table A1 (in Appendix A to this report) clarifies this distinction. Figure A1 shows important NI assets.

The DoD has adopted the NI concept in an attempt to identify, characterize, and monetize NI assets at installations. The motivation behind this effort is to more effectively and efficiently use these assets, and to plan for

their continued availability. The *Defense Installation Strategic Plan* recommends several measurement techniques to support installation capability, including the need to "identify requirements for land, water and air resources to support current and future mission, examine existing capabilities, and perform gap analysis" (DUSD I&E 2006, p 8).

The Air Force has conducted the NI valuation process at several installations. Appendix A outlines the steps of the process and gives examples of NI found Eglin Air Force Base (AFB), FL. Figure A2 outlines the valuation process steps:

1. Characterize the assets.
2. Determine the goods and services present as represented by the assets.
3. Gather relevant economic data for the goods and services.
4. Sum these using an "accounting framework that allows for aggregation of values."

Ecosystem services are included in this process as physical assets that provide services such as: climate regulation, waste assimilation, disturbance prevention, nutrient regulation, habitat provision, soil formation, pollination, recreation, and aesthetics; all of which are included as ecosystem services in this work, with the exception of recreation and aesthetics. The methods proposed by the Air Force valuation methodology to estimate the dollar value of these physical assets include:

1. *Benefits Transfer* — "an indirect approach that uses values from primary studies or market appraisals conducted off-site to generate values for assets on-site, adjusting for differences between the sites" (DoD 2006, p 9-13)
2. *Travel Costs* — an indirect method that uses the expenses people pay to travel to a recreational location as a proxy for the value of the resources at the destination
3. *Hedonic Pricing* — an indirect method that compares values of homes near natural assets with homes further away, accounting for other variables and the difference represents the value of the natural feature
4. *Contingent Valuation* — a direct solicitation method where individuals are asked how much they are willing to pay for protection of a resource (their stated preferences)
5. *Substitute Costs* — estimation based on providing a substitute for the physical asset and its associated services

6. *Avoided Costs* — estimation based on costs *not* accrued because the services are available (e.g., the New York City and Everglades examples in this document)
7. *Restoration Costs* — costs to restore the physical asset so services become available (i.e., restore a wetland).

The Air Force valuation method also recognizes that even with these economic estimation tools, there will also be physical assets of non-monetary value. The method proposes to capture these by their description, such as through a habitat equivalency analysis:

> Resource Capability and Resource Valuation together provide the Commander with a complete view of the deficiencies and/or potential additional capability of the installation's natural infrastructure, and the valuations needed to determine the cost-benefits of various risk management actions (DoD 2006, p 9-13).

The Office of the Secretary of Defense (OSD) established an NI Capability Workgroup (NICWG) in 2004 to support the Air Force's efforts and develop policies and standards of practice based on the Air Force's experience. The most recent activity by the NICWG is to identify potential Environmental Credits (ECs) to track and use as appropriate. ECs are defined as "a specific subset of NI assets – they are statutory assets that are enabled by policies to reduce or mitigate pollution and other impacts on ecosystems from human activities. ECs are typically salable/tradable ... [and include]: air emissions credits (emission reduction credits, tradable allowances); carbon credits; wetland/stream mitigation credits; habitat/species credits (conservation banks); and water quality credits" (BAH 2007). These efforts will link the mitigation offset activities to operational and economic values along with other estimation techniques.

Mitigation Offsets

Wetland mitigation offset projects have been completed for regulatory purposes on DoD installations. These are classic examples of land that is enhanced or restored to create wetland acreage credits. Activities that fill or otherwise impact wetlands elsewhere on the base can then draw from these credits. Fort Stewart, GA created wetlands by lowering water level in an existing reservoir (the Canoochee Creek Reservoir 1080-acre impoundment) to original elevations (Padgett and Harrell 2001). The site is

now an approved wetland mitigation bank. The Marine's Camp Lejeune in North Carolina maintains a 1250-acre wetland mitigation bank in the Greater Sandy Run Area to mitigate wetland impacts in the development of training ranges (MCB Camp Lejeune EMD 2002).

McGuire AFB, NJ, was able to trade 'headroom' in its volatile organic compound (VOC) 'budget' and accommodate increased mission requirements even though the installation is in an EPA-designated ozone non-attainment area. Pollution prevention activities at the AFB had reduced its overall VOC emissions, and it was able to 'trade' these reductions for increases in nitrogen oxide caused by the increase in mission (Koetz 2004).

These examples are indications of how 'assets' can be created and then used to support the mission while maintaining the same level of environmental quality. In particular, ecosystem services are created to mitigate increased use of these services elsewhere. These examples are very local in nature and rely heavily on the regulatory drivers to be relevant. They are classic examples of market-based approaches since the regulated entity (a military instillation) was able to meet its regulatory obligation in a manner that was most efficient for that entity.

Acquisition of Development Rights

The Army Compatible Use Buffer (ACUB) program focuses on protecting land adjacent to test and training ranges at Army installations. The Army enters into cooperative partnerships with other stakeholders to leverage DoD dollars and ensure compatible land use. Conservation easements are held by partners and managed for various purposes, primarily habitat protection and farmland preservation. This program has expanded greatly since the first cooperative arrangement at Fort Bragg, NC, was created to provide habitat for the RCW outside the installation's boundaries. Over the 15 years since then, Congress has expanded the authority of the armed services to enter into these partnerships and approximately 80,000 acres of wildlife habitat outside of military installations has been protected (John Housein, Wildlife Biologist at USAEC, email correspondence, 29 January 2008). Conservation easements are commonly used to obtain development rights, and the program relies on willing sellers.

The acquisition of development rights in this program has typically been focused on two goals; compatible land use in the vicinity of installations and habitat preservation. The experience gained over the years is leading to more creative and expanding roles for the ACUB program. In essence, the land being set aside has military value, ecological value. and economic value; the ACUB program can help capture these values and increase the financial incentives to landowners to encumber land for preservation. In addition, regulatory requirements can be met in a proactive manner. Land or development rights obtained through the ACUB program are now being considered to help installations meet multiple goals and "dramatically increase benefits" (Speth and Natoli 2007). Wetland mitigation offsets pursued by the military have typically been on its own land (cf. Chapter 5), but many installations are running out of real estate to make such set-asides within the installation boundaries. The ACUB is a possible venue to establish acres of set-aside for future wetland mitigation or conservation banks (Speth and Natoli 2007). This approach is conceptual for now, but represents real opportunities to capture *all* the value in preserved land—economic, environmental and military—making this land use competitive to developed uses.

Fort Drum, New York

Natural resource planners at the U.S. Army Environmental Command (USAEC) and Fort Drum, NY, are working to establish mitigation credits on ACUB land *before* they are needed by the installation. These credits will then be available to "help the Army reduce on-site wetland mitigation costs and protect key training areas" (Speth and Natoli 2007). Environmental compliance is typically conducted one permit at a time, in reaction to one range project at a time—a process that can be costly and cause delays. The planners hope to do more with each piece of protected land, in this case restoring or enhancing wetland acreage on ACUB land to build a 'bank' of credits that will be needed as operations at Fort Drum expand.

There are several challenges for this expanded the role of the ACUB program. The government and its partners' contribution are often limited to the fair market value for the land enrolled in the ACUB program. Required standards and practices do not allow for consideration of the "million dollar range on the other side of the fence," or investments made into conservation enhancements on a given parcel. As has been noted in this work,

the ecosystem services represented by an undeveloped parcel of land do not have an economic value, even though these services have environmental and military value. Even if the installation and its partners are willing to pay beyond its appraised value (since its real value is much more), there are limits on what the government and its partners can offer to potential sellers. Developers, on the other hand, are not limited by such restrictions and can offer higher prices to landowners in land speculation deals. The 'highest and best use' criteria used for conducting traditional market appraisals *undervalues undeveloped land*.

The National Defense Authorization Act for Fiscal Year 2008 (NDAA) has language to help address this issue in Section 2825: "Agreements to Limit Encroachments and Other Constraints on Military Training, Testing and Operations." This language allows the Government to exceed the 'fair market value' for its portion of the exchange:

> but only if-- (i) the Secretary concerned provides written notice to the Committee on Armed Services of the Senate and the Committee on Armed Services of the House of Representatives containing--(I) a certification by the Secretary that the military value to the United States of the property or interest to be acquired justifies a payment in excess of the fair market value of the property or interest; and (II) a description of the military value to be obtained.

This language represents progress in the ongoing efforts to enable real estate transactions designed to preserve land near military installations, and should be monitored as it is used by the Services going forward.

Other important considerations that enable the expanded ACUB approach include the need for a regulatory driver (such as the Section 404 of the Clean Water Act permit requirements), and likewise the cooperative involvement of the regulators. The preserved land must have its ecological value established by solid scientific assessment (Nancy Natoli, ACUB Team Leader at USAEC, and John Housein, Wildlife Biologist at USAEC, telephone interview, 29 October 2007).

Marine Corps Air Station (MCAS) Beaufort

The second example of addressing encroachment concerns with market-based mechanisms can be found at Marine Corps Air Station (MCAS)

Beaufort, SC. This coastal MCAS is experiencing residential development within the Air Installation Compatible Use Zone (AICUZ), and is developing a TDR program jointly with the surrounding communities to encourage compatible development within the AICUZ. This effort is a result of the Lowcountry JLUS that was completed for the air station and the resulting recommendations. The goal is to "develop a workable program to mitigate the economic impact of restrictions on the use of owners' land within the MCAS Beaufort AICUZ Overlay District" (Lowcountry COG 2007). Sending areas will be those included in the overlay district and receiving areas will be zones designated for higher density development. Regular meetings are being held with stakeholders from the installation, the Councils of Beaufort County, the City of Beaufort, and the Town of Port Royal. Detailed procedures must be developed, including: changes to the Comprehensive Plans and zoning ordinances, inter-jurisdictional coordination, administrative mechanisms, and formulas for transfer (Lowcountry COG 2007). The MCAS represents an important economic driver to the community, and its continued viability is an ongoing concern as the cities and villages near the base continue to grow.

An important lesson from the MCAS example is that the installation can only serve as an interested stakeholder in the development of a TDR market. The local governments must establish the legal framework and gain the support of the development community to ensure successful outcomes. It is not yet clear if the DoD will be able to purchase TDRs and 'retire' them – in this way ensuring compatible use in a manner that meets economic requirements of the landowners and developers. This case should be monitored as it progresses since it is breaking new ground in cooperative ventures between military installations and their host communities.

Establish an Explicit Market

Colorado Shortgrass Prairie Partnership

The conservation efforts in Colorado involving Fort Carson and the Shortgrass Prairie Partnership are a success story for cooperative relationships and valuation of ecological assets at a regional scale. Natural resource planners at Fort Carson realized that endangered species conservation efforts would be more effective at the regional scale. Attempting to manage and protect endangered species within the installation fence line is not based on fundamental ecosystem management principles. The Partnership

has been developing for several years and has established a common vision (Shortgrass Prairie Partnership 2007):

> The Shortgrass Prairie Partnership provides landowners and managers, public agencies and private organizations the opportunity to **collaboratively work together to ensure the long-term viability of the native species, natural communities and ecosystems of the Central Shortgrass Prairie** ecoregion **while promoting the continued existence of economically productive landscapes** that sustain local communities.

An ecoregional assessment has been completed to identify the location and extent of species, ecosystems, and habitats of conservation concern, and actions necessary to successfully maintain these in the future. The Partnership is developing methods to measure and monitor progress toward its conservation goals. Conservation banking, conservation easements, and a credit trading scheme are all possible routes the Partnership will take in the future, but at this point, the focus is on characterization of ecosystem structure and function along with consensus building among stakeholders for implementation strategies.

Lessons learned from this ongoing effort include importance of developing scientifically-based assessment and measurement techniques in a methodical program. Such a program is needed to ensure a proposed credit system is viable for meeting ecosystem conservation goals. There are no one-size-fits-all solutions; each ecosystem will have unique problems from the economic, environmental, and operational perspectives. Proposed solutions must correspond with these unique situations and be developed with regional partners. Any trading scheme must be based within a clearly-defined geospatial context. Partnerships that cover a large spatial area like the Shortgrass Prairie Ecoregion take time and a concerted effort to build, but are necessary for including ecosystem services in the economic and political decisionmaking (Gary Belew, Land Use Ecologist, Range Lands and Ecosystem Branch USAEC, Telephone Interview, 29 October 2007).

Fort Bragg Regional Agriculture Sustainability Program

Sustainability planning and community engagement in the region containing Fort Bragg, NC have recently joined with the Base Realignment and

Closure (BRAC) Regional Task Force (RTF) in a unique program to provide economic development to a struggling agricultural sector. This new program has many goals for the region, and it intends to "help farmers transition from tobacco to other commodities to serve the imminent population growth at Fort Bragg by linking the food, fuel, and fiber needs of America's largest Army installation to the agricultural capacity of the region" (BRAC RTF 2007). This ambitious effort is relevant to this work because it uses economic development drivers to influence land use and the ecosystem services related to land use. Specifically, the effort will help farms surrounding Fort Bragg to remain viable. Agricultural land uses are compatible with training; they provide encroachment buffers, which is an ecosystem service that has value, but a value not accounted for by traditional economic markets. This case should be monitored as it progresses because it too, like the MCAS Beaufort, is breaking new ground in cooperative ventures between military installations and their host communities.

7 Conclusions and Recommendations

Conclusions

This work has defined ecosystem services as those natural resources that present the most difficult policy and planning challenges because the benefits derived are not captured by current economic methods of valuation. Market-based approaches help to bring the full range of values represented by ecosystem services into decisionmaking and market transactions. The DoD currently attempts to ensure compatible land use though land use controls (e.g., zoning regulations) and with the purchase of development rights (e.g., conservation easements). Both of these methods are effective but cannot meet increasing scarcities, especially those that are regional in nature. Land uses that support and/or are compatible with military training need this value to be reflected in the market price. The red line in Figure 5 represents the potential *combination* of ecosystem commodities and services. When the price of land incorporates *all* of the environmental, military, and economic value represented by that land use, then undeveloped land use has the potential to be competitive to developed uses. Successful operational and environmental outcomes over the long term depend on such a complete valuation process.

Market-based approaches commonly require regulatory drivers to implement, which often take a great deal of time and effort to design and institute. These approaches also require solid scientific foundations and buy-in from the community and regulated stakeholders. It is also important to understand that ecosystem-based solutions cannot be standardized; they must reflect the unique place and social context where the services are being generated and used. Ultimately, these approaches seek to alter the behavior of market actors to ensure the continued supply of ecosystem services. Government regulation, property rights, and social norms all influence behavior and can be used to help create a more completed valuation process for the management of ecosystem services. There are many challenges to implementing market-based approaches, such as monetizing ecosystem services, defining the ecosystem production functions, and devising incentives. It is imperative to overcome these challenges to support and preserve the essential role these natural resources play in supporting the military testing and training.

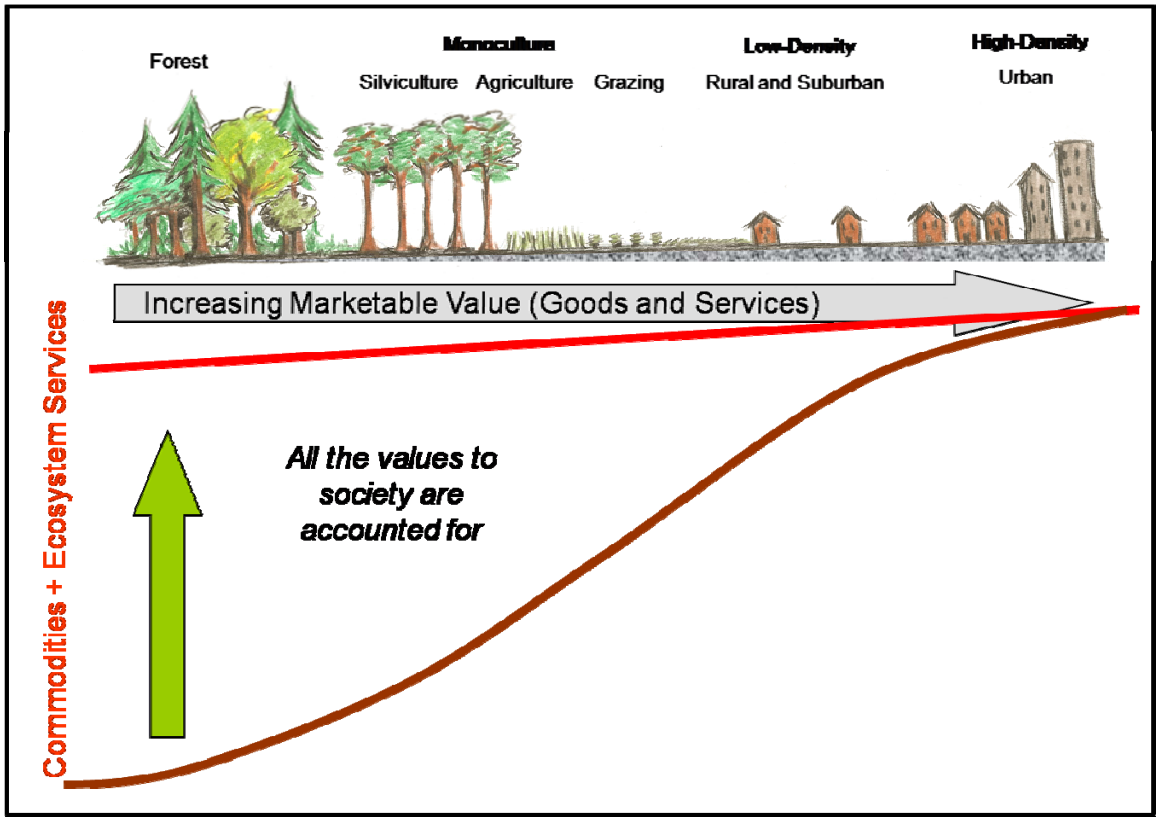

Figure 5. Accounting for all values in land use decisions.

Recommendations

It is recommended that, as the DoD continues to develop programs and policies focused on ensuring the provision of ecosystem services in support of operational and environmental objectives, it should:

1. *Devise Solutions that Reflect the "State of the Art."*
   The DoD should not pursue an approach to managing its natural resources that is unique to the DoD. This is a dynamic field with many relevant research projects and implementation examples the DoD can draw on and learn from. There is a need to interact with outside partners and academia, engage in emerging markets, and use a common language.
2. *Include Ecosystem Service Values in Cost-Benefit Analysis.*
   As this work has discussed, ecosystem services have environmental, military, and economic value. The DoD should continue to develop accounting and valuation methods that capture these values. These methods will enable important ecosystem services to be included in land acquisition strategies. A more complete accounting will help en-

sure that decisionmakers consider how natural resource allocation decisions affect ecosystem services.

3. *Look for Partners with Common Interests.*
   The DoD should constantly search for opportunities in which military interests can be aligned with other interests in the region (habitat preservation, watershed preservation, growth management, etc.) to maximize the use of resources and achieve multiple objectives.
4. *Investigate Non-Market Based Approaches.*
   Other methods for protection and provision of ecosystem services not explored in this work may also prove effective. The DoD should explore and advocate these other approaches at the Federal environmental policy level, including information disclosure, and management and planning/assessment requirements. Information management is crucial in this effort, since, as Ruhl et al. (2007, p 273) note:

   > Natural capital and ecosystem services face a bit of a catch-22 dilemma: because current law and policy do not adequately account for natural capital and ecosystem service values, little reliable information is available about them, but law and policy cannot intelligently account for them through regulatory prescriptions without such information. A way out of this predicament that has proven remarkably successful in other contexts is to require disclosure of information without attaching regulatory consequences directly thereto.

   The National Environmental Policy Act (NEPA) is a planning and assessment approach that requires that potential negative impacts to the environment from proposed Federal actions be identified and assessed prior to taking the action. Even though NEPA cannot stop the Federal agencies from taking proposed actions (regardless of impacts), the public involvement and procedural requirements of the law have had a significant impact on Federal agency decisionmaking. NEPA has also created a wealth of professional expertise in understanding and assessing environmental impacts associated with human activities (Clark and Canter 1997; Karkkainen 2002; Mazmanian and Nienaber 1979). As ecosystem services begin to be identified and valued for decisionmaking purposes, it is logical that NEPA Environmental Impact Statements will incorporate the new perspectives of value.
5. *Support Pilot Projects at Installations with Critical Needs.*
   As discussed earlier in this report (p 2), Fort Benning is one example of an installation with critical natural infrastructure requirements. Fort

Benning's mission will be expanding as a result of BRAC, and it may not have enough real estate to mitigate impacts from the construction of new training ranges. Other cases similar to Fort Benning exist. The DoD should support pilot projects in these cases that will specifically identify and address ecosystem service shortages with experimental or modified market-based approaches. The regulatory environment is changing rapidly. This climate of change provides opportunities for innovative solutions, e.g., the proposed *Recovery Credit Guidance* by the USFWS and the new authority for valuation provided by the NDAA.

6. *Conduct Ecosystem Service Assessments at the Regional Scale.* Ecosystems function at many scales, and accounting and assessment methods are needed to address each relevant scale. Certain issues, such as potable water provision, are highly dependent on activity at some distance from the installation boundary. Methods for analyzing these regional land use issues are needed to help inform decisionmaking and ensure the long-term provision of ecosystem services necessary for military testing and training.

Acronyms and Abbreviations

Term	Spellout
ACUB	Army Compatible Use Buffer
AFB	Air Force Base
AICUZ	Air Installation Compatible Use Zone
BAH	Basic Allowance for Housing
BRAC	Base Realignment and Closure
CBA	Cost-Benefit Analyses
CEERD	U.S. Army Corps of Engineers, Engineer Research and Development Center
CERL	Construction Engineering Research Laboratory
CFR	Code of the Federal Regulations
CO	carbon monoxide
COG	Council of Governments
CRP	Conservation Reserve Program
CRP	Conservation Reserve Program
DC	direct current
DoD	Department of Defense
DUSD I&E	Deputy Under Secretary of Defense, Installations and Environment
EBI	Environmental Benefit Index
EC	Environmental Credits
EMD	Environmental Management Division
ENS	Environmental News Service
EPA	Environmental Protection Agency
ERDC	Engineer Research and Development Center
ES	Executive Summary
ETN	Environmental Trading Network
FRESP	Florida Ranchlands Environmental Service Project
GHG	Greenhouse Gas
ISR	Installation Status Report
IUCN	International Union for Conservation of Nature and Natural Resources
JLUS	Joint Land Use Study
MCAS	MCAS
MCAS	Marine Corps Air Station
MCB	Marine Corps Base [Camp]
MEA	Millennium Ecosystem Assessment
NDAA	National Defense Authorization Act
NEPA	National Environmental Policy Act
NI	Natural Infrastructure

Term	Spellout
NIA	Natural Infrastructure Assessment
NICWG	Natural Infrastructure Capability Work Group
NIM	Natural Infrastructure Management
NRC	National Research Council [of the National Academies of Science]
OECD	Organization for Economic Co-operation and Development
OSD	Office of the Secretary of Defense
PACE	Purchase of Agricultural Conservation Easements
PDR	Purchase of Development Rights
PES	Payments for Ecosystem Services
RCW	Red-cockaded Woodpecker
RFF	Resources for the Future
RTF	Regional Task Force
SMEs	Subject Matter Experts
SO2	Sulfur Dioxide
SROC	Senior Readiness Oversight Council
TCEQ	Texas Commission on Environmental Quality
TD	technical director
TDR	Transfer of Development Rights
TMDLs	Total Maximum Daily Loads
TNT	trinitrotoluene
TR	Technical Report
UMI	University of Michigan
UNFCC	United Nations Framework Convention on Climate Change
US	United States
USAEC	U.S. Army Environmental Command
USAF	United States Air Force
USEPA	U.S. Environmental Protection Agency
USFWS	U.S. Fish and Wildlife Service
VOC	Volatile Organic Compound

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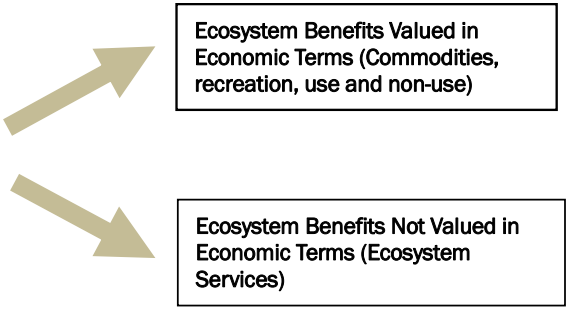
Appendix A: Natural Capital and Natural Infrastructure Concepts

Table A1. Capital and infrastructure terms.

Term	Definition	Term	Definition
Natural Capital	Stock of resources and living systems from which flows resource harvest and extraction, as well as the essential ecosystem services of a bio-region*	Natural Infrastructure	A region's available natural resources that may be used for the purposes of public services, products, habitat and/or human enjoyment.
Built Capital	The built structures and manufactured items that support basic human needs†	Built Infrastructure	The physical structures and networks built to support regional connectivity, mobility and resource needs.
Social Capital	The networks, norms of reciprocity, and mutual trust that exist among and within groups and communities ‡	Social Infrastructure	The physical structures, governance mechanisms, social institutions, and social networks that contribute to community well-being and human health in a region.

Sources:
*http://www.humboldt.edu/~envecon/Indicators/naturalcapital.htm
†http://www.sierraclub.org/sustainable_consumption/toolkit/lesson2.pdf
‡http://www.latech.edu/tech/rural/files/resourcesmodule/@random448992fdb62ed/1149867185_NRIposter.pdf



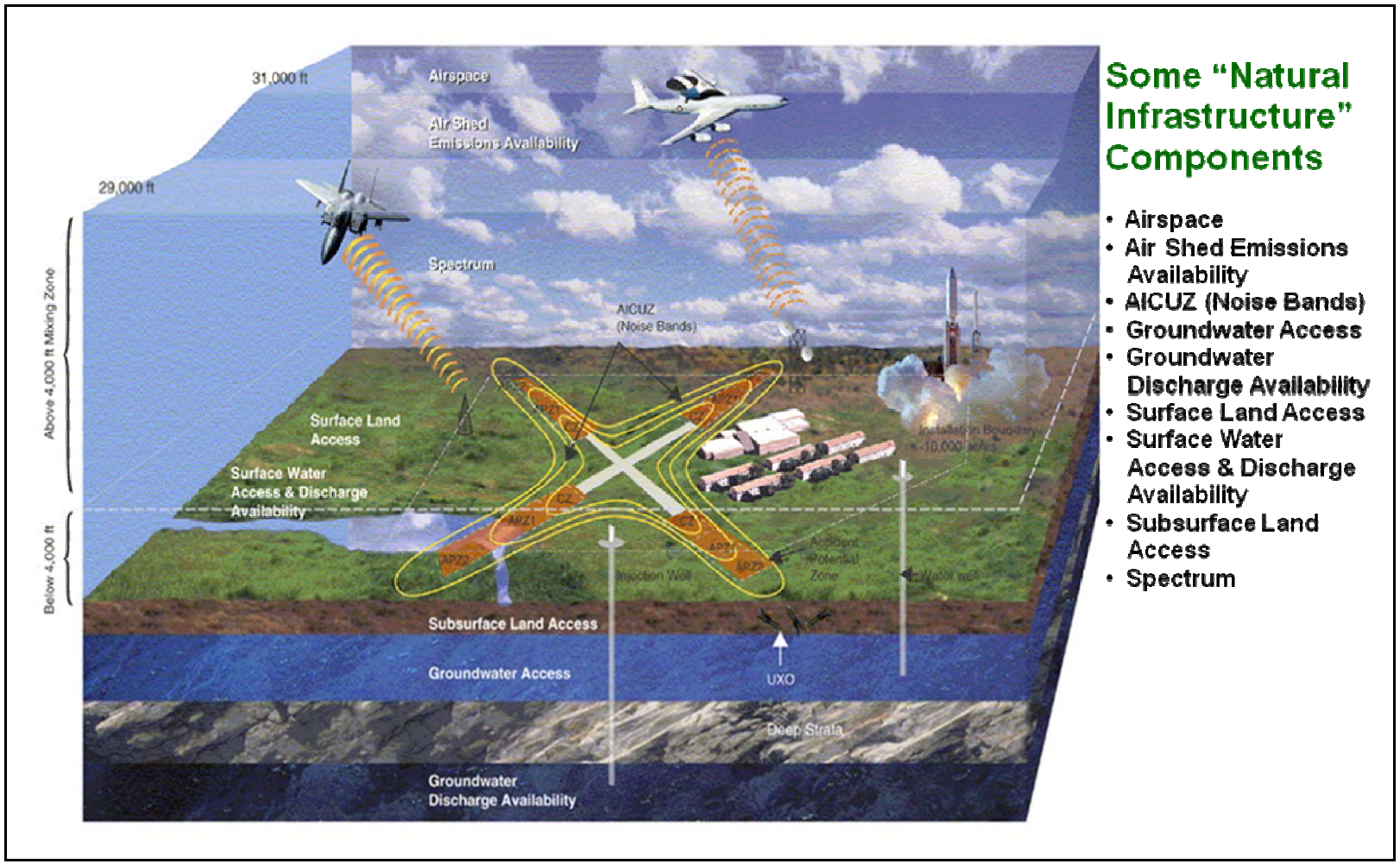


Figure A1. Representation of natural infrastructure (Source: Ms. Maureen Koetz Deputy Assistant Secretary, US Air Force).

Table A2. Resources included in natural infrastructure assessment and valuations (Source: Maureen Koetz).

Resource	Air	Water	Land
Operational Attribute	• Airshed (emission carrying capacity • Airspace • Airwaves (spectrum)	• Watershed (Supply, Quality, Discharge Capacity) • Ecology	• Area • Ecology • Discharge Capacity
Asset	• Emissions permit • Special Use Airspace • Frequency Allocations	• Water rights • Discharge Permit • Recharge capacity • Wetlands/Species	• Cantonment / Support Services • Buffer Zone • Training Areas • Material disposal capacity • Species Habitat

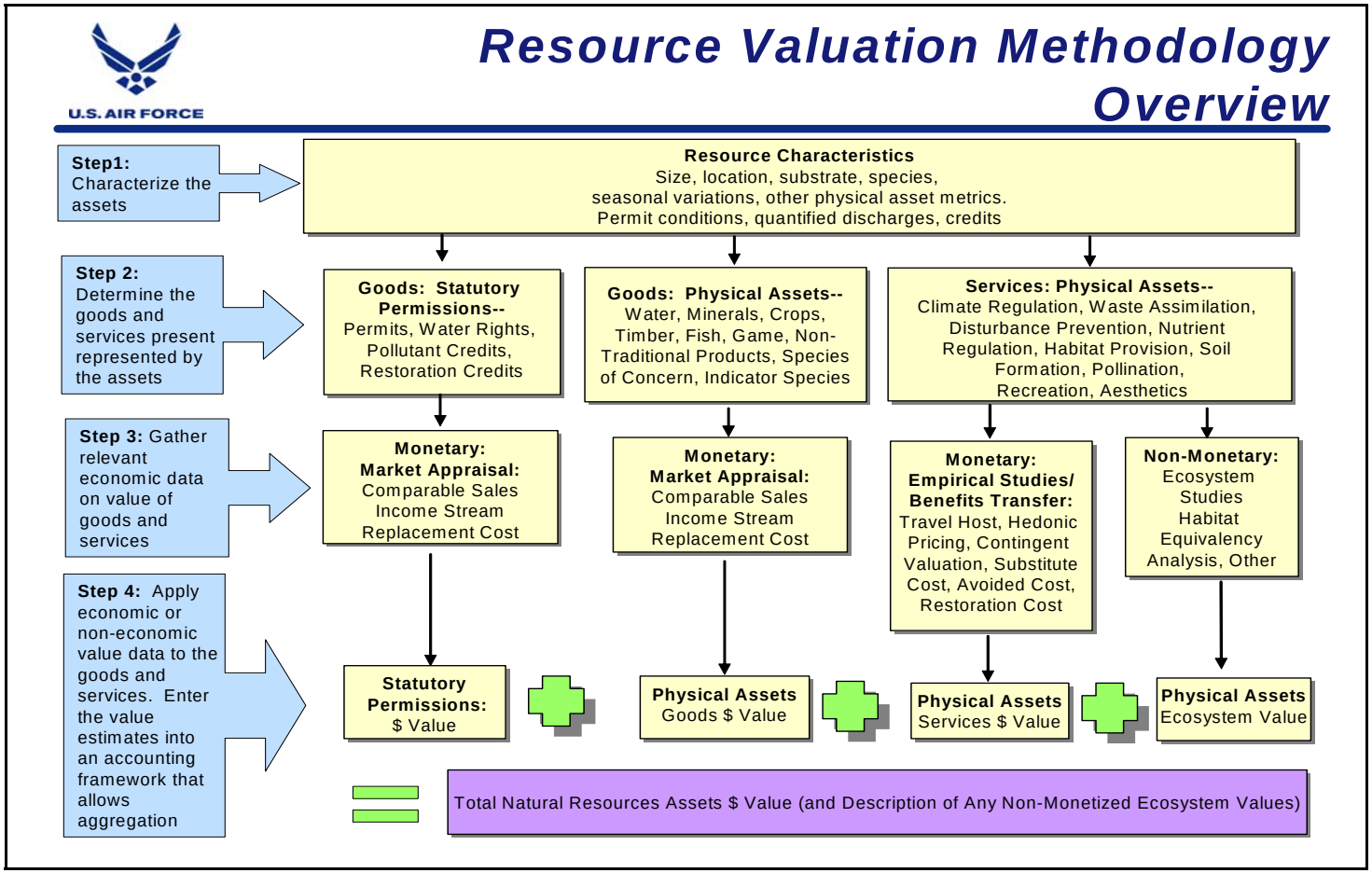


Figure A2. Resource valuation for natural infrastructure (Source: Slide from U.S. Air Force Presentation at Joint Services Environmental Management Conference, 2005, by LT COL Rod Croslen).

U.S. AIR FORCE

Characterization of Natural and Cultural Resources Evaluated at Eglin

Resource	Characterization	Goods	Services
Forests	400,000 acres of Longleaf Pine Sandhills Ecosystem	Timber and non-traditional forest products	Carbon sequestration, habitat provision and biodiversity, recreation*
Wetlands/Riparian	64,299 acres, 80% in good condition, 1,158 miles of streams	Timber and non-traditional forest products, fish	Water regulation and supply, waste assimilation, nutrient regulation, habitat, soil formation, disturbance prevention, recreation*, aesthetics
Barrier Islands	6,202 acres, 16 miles of barrier islands	Land value in mission (conservation) easement	Interior bay and coastline storm protection, habitat, recreation*
Cultural and Historic	1,900 discrete historic properties, archeological sites & associated artifacts.	Buildings (office, residential, laboratory, industrial), archeological sites & associated artifacts	Heritage preservation & protection, public awareness, education, research
Air Shed Resources	Historical operational emissions, emissions allowances, air shed regulatory or procedural head room	Emission rights - historical mobile, fugitive & stationary sources, permit head room	Air shed emissions head room under existing laws and regulations
Water Discharge Rights	Historical wastewater and storm water discharges, NPDES/other permit allowances and actual use	"Rights" to historical discharges within NPDES/other permit allowances	"Head room" between historic use and NPDES/other permit allowances

*Recreation is evaluated separately

Figure A3. Characteristics of resources at Eglin AFB (Source: Slide from U.S. Air Force Presentation at Joint Services Environmental Management Conference, 2005, by LT COL Rod Croslen).

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14. ABSTRACT

Military installations face increasing competition for important natural resources that provide ecosystem services not captured by current economic methods of valuation. Ecosystems naturally assimilate waste, attenuate noise, form soil, control erosion, regulate surface water flow, and buffer installations from surrounding communities. These services mitigate environmental impacts of training, help installations comply with environmental regulations, and ultimately enable the Department of Defense (DoD) to conduct training on installation lands. When undeveloped or rural land is converted to urban uses, valuable ecosystem services are lost. Accounting methods are needed to track the quantity and quality of ecosystem services and to inform decisionmaking such that needed services continue to be available. Market-based approaches can estimate the dollar value of ecosystem services and create financial incentives or markets for their valuation and trade. The DoD has recently begun to use these concepts in its policies and at its installations. This report investigates how to provide ecosystem services through market-based approaches. While there are significant institutional barriers, the authors concluded that market-based approaches can help ensure the continued supply of these services if these problems associated with monetizing ecosystem services, defining ecosystem production functions, and devising incentives can be resolved.

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