NICHOLAS SCHOOL OF ENVIRONMENT

Valuing Nature in Business

A Case Study of Chemical Manufacturing and Forest Products Industries

by

Peter Browning
Mimi Gong
Tianyang Hu
Charles Marx
Taichi Natake

Dr. Lynn Maguire
Dr. Sheila Walsh Reddy, The Nature Conservancy

4/25/2014

Masters project submitted in partial fulfillment of the requirements for the Master of Environmental Management degree in the Nicholas School of the Environment of Duke University

Abstract

Over the past several decades, there has been an increased realization of the extent to which the means of production in human society depend on and impact increasingly fragile natural systems. Working with our client, The Nature Conservancy, we researched trends in ecosystem valuation within the chemical manufacturing and forest product industries, discerning ways to identify and evaluate future ecosystem investment opportunities. This research resulted in a framework that businesses could use to identify future ecosystem service opportunities and then score the opportunities' business values using a multi-criteria analysis approach.

We identified potential ecosystem service opportunities by overlaying classifications of business risk on major operational subsectors within the industries, populating the resulting table with key ecosystem impacts and opportunities. Through the application of this process, we identified three hypothetical ecosystem service projects applicable to both the chemical manufacturing and forest product industries and used them to test our scoring framework. The identified projects were constructed wetlands for wastewater treatment, coastal habitat protection for storm surge protection, and forest carbon sequestration. We ranked the business value of each project using five criteria important to businesses: financial value, reputational benefits, environmental risk reduction, political and regulatory enabling conditions, and level of knowledge and activity in the field. According to our research, businesses emphasize financial benefits most highly when evaluating potential investments, so we weighted financial values most heavily in our ranking scheme. Our analysis indicated that a forest carbon sequestration project had the highest potential business value relative to the other project types due to its higher expected financial benefits. The constructed wetland project, which also had a relatively high expected financial benefit, followed second. Finally, the coastal habitat protection project had the lowest relative business value due to high costs, a low level of scientific knowledge, and weak regulatory support.

The identification and ranking methodologies are designed to be flexible, allowing adaptation for use given varying business objectives. The weights on the five valuation criteria can be adjusted to reflect a business's concerns. This scoring methodology is useful for businesses because few tools exist to enable comparative analysis of business ecosystem service investments. We believe this tool provides a useful approach to determining the value that nature and ecosystem services provide to a wide range of businesses, and we recommend its application outside the chemical manufacturing and forest products industry for further refinement.

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1 Introduction and Problem Definition

Over the past several decades, it has become increasingly apparent that the means of production in human society impacts and depends upon increasingly fragile natural systems (de Groot, 1987; Costanza et al., 1998). However, businesses and governments have long undervalued services provided by these natural systems, broadly known as ecosystem services. A number of recent reports have detailed the extent to which economic activity relies on biodiversity, natural ecosystems, ecosystem health, and the degree to which society —and businesses, in particular—may need to incorporate these ecosystem values into their decision-making processes. These reports include the Millennium Ecosystem Assessment (2005) (MEA), the Economics of Ecosystems and Biodiversity (2012) (TEEB), and various U.S. government publications (e.g., EPA, 2009), which elaborate a system of classifying ecosystem services and provide frameworks to incorporate them into decision-making. Nevertheless, the valuation of ecosystem services in business decision-making remains both underdeveloped and underappreciated.

Despite an increased desire to incorporate ecosystem service values into business decisions, identifying when and where ecosystem services should be valued and actively managed remains difficult from a business standpoint. The TEEB reports indicate this may be partly due business leaders' lack of understanding of the degree to which ecosystem decline puts their businesses at risk, or to the lack of visibility of such issues as compared to more immediate risks such as the global recession of 2009 (TEEB, 2012). Addressing these gaps in understanding may lead to more sustainable business practices and result in a more sustainable society. Even business leaders moving to integrate ecosystem service values into their businesses see execution of such plans as rife with risk and uncertainty when compared with other investment decisions (Scherr et al., 2006; Sveaskog, 2012). In other words, prioritizing ecosystem services in a world of unknowns remains difficult. We intend to simplify this aspect of the decision-making process.

Prioritization of ecosystem service opportunities through early identification of ecosystem trends and assessment of emerging opportunities may allow some businesses to gain a competitive advantage in corporate ecosystem service management or in the development of new products and services (TEEB, 2012). Some companies are already working to recognize the value of ecosystem services in their decision-making processes. In particular, The Dow Chemical Company (Dow) has partnered with The Nature Conservancy (TNC) to conduct pilot studies to develop a broader strategy for incorporating the value of ecosystems into their business management model (TNC, 2013). Their first pilot project in Freeport, Texas, evaluated prospects for developing environmentally driven alternatives to traditional infrastructure (i.e., replacing "grey" infrastructure with "green" infrastructure options). For example, they looked into urban reforestation as an alternative to air scrubbers to meet air quality standards and into wetland restoration as an alternative to building storm-surge levees. TNC and Dow are also partnering on a second pilot at the site of a new joint venture in Brazil to see how landscape-scale planning in an area of expanding sugarcane production can lead to better environmental outcomes and cheaper compliance (TNC & Dow, 2013).

Working with TNC, we have examined trends in the growing fields of ecosystem service identification and valuation. We examined these trends, as well as some unique ecosystem service management opportunities, to determine which specific business sectors have the greatest opportunity to undertake active management of ecosystems, and why. In particular, we created a scoring framework that will allow businesses to rank the business value of ecosystem service opportunities, based on their technical, political and financial feasibility.

The thrust of our examination focused on two sectors: chemical manufacturing, an ongoing interest of our client TNC, and the forest products industry, which many of us are familiar with as Masters of Forestry students. Our review of the forest products industry was limited to goods and services managed or produced by large corporations, notably timber, structural wood products, and pulp and paper products. Finished products such as wood furnishings and cabinetry were not included due to the diversity of products, processes, and markets in play. While we identified a number of potential opportunities for businesses to engage in ecosystem service management, we placed greater focus on a suite of ecosystem service projects that are well understood, or that our research indicated have the potential to provide greater business value. The list of services considered, and their connection to our sectors of interest, are detailed in Table 1. Further background on ecosystem services and their history is presented in Box 1.

Table 1: A description of ecosystem services examined in this paper.

Ecosystem Service	**Description**
Air quality regulation	Chemical manufacturing has air pollution implications; forests can aid in the capturing of criteria air pollutants and sequester atmospheric CO_2
Water provision	Both chemical and forest manufacturing plants require water in their processes; forests also play a role in the water cycle through transpiration, water capture, and infiltration.
Water quality regulation	Both chemical and forest product manufacturing plants can have detrimental water quality impacts; timber harvesting can also be detrimental to water quality.
Soil quality regulation	Chemical wastes can negatively impact soils; forest growth depends on healthy and fertile soils, and harvests can reduce soil quality.
Cultural services	Forests and open spaces provide opportunities for recreation, hiking, hunting and fishing, as well as aesthetic benefits.
Biodiversity maintenance habitat quality	Forests provide habitat for a range of species; various forestry practices can be detrimental to biodiversity and habitat quality.

Box 1 – Further Background on Ecosystem Services and their Values:

The U.S. Environmental Protection Agency (2009) and the Millennium Ecosystem Assessment (2005) have worked to develop a common classification scheme for the range of goods and services that ecosystems provide. Ecosystem services that provide direct inputs into the economy are known as provisioning services; this class of ecosystem services includes food, fiber, timber, and fresh water. Other ecosystems services help regulate the environment by supporting other services. Known as regulating and supporting services, they include water purification, climate control, habitat provision and soil formation. The final class of ecosystem services, cultural services, contributes to spiritual, cultural and aesthetic well being. Although there are a number of methods for determining the economic value of regulating and provisioning services, they often are difficult to apply in practice. (MEA, 2005; USEPA, 2009).

2 Overview and Methods

Many organizations have developed descriptive indicators of the value of ecosystem services and put considerable effort into quantifying ecosystem service benefits. However, despite the ongoing efforts of environmental non-governmental organizations (NGOs) (e.g., TEEB, 2012), businesses struggle to identify and value the risks and opportunities posed by ecosystem exposure and ecosystem management (Millennium Ecosystem Assessment, 2005, WRI, 2012). Here we develop a process businesses can use to identify opportunities for incorporating ecosystem values into their decision-making procedures. We investigated particular cases in the chemical manufacturing and forest products industries, using techniques applicable within any industry or business. Using this scoring framework, businesses can identify opportunities and rank each opportunity's relative feasibility.

To complete our objectives, we first examined historical trends in the industries of interest and identified possible opportunities for them to benefit from ecosystem service valuation and management. We then developed a system for businesses to prioritize their ecosystem services opportunities.

Our approach consists of three parts, which our paper broadly follows:

1) analysis of sustainability and ecosystem service trends in the chemical and forest product industries;
2) identification of ecosystem service opportunities in the two industries; and,
3) prioritization of ecosystem opportunities.

We developed a system for analyzing the opportunities discovered based on five criteria. These criteria include a project's financial value, the level of scientific knowledge and activity regarding such projects, the reputational benefits it offers, political and regulatory enabling conditions, and the degree to which it reduces the risk of environmental hazards.

Step 1: Analysis of Sustainability and Ecosystem Service Trends in the Chemical and Forest Product Industries

By searching peer-reviewed scientific publications, grey literature, and government white papers, we analyzed the environmental and sustainability strategies of companies in each industry to determine the historical context of their broader engagement with environmental concerns and to assess how they have engaged in service-related opportunities.

According to the World Business Council for Sustainable Development's (WBCSD) Guide to Ecosystem Valuation (2011), businesses address ecosystem risks and value ecosystem services in the context of previous environmental and sustainability steps. Ecosystem valuation is a recent corporate development, growing out of the companies' trajectory of environmental engagement, usually beginning with regulatory compliance measures, moving towards appreciation for efficiency as cost-saving measure, then extending beyond the regulatory and efficiency constructs to identify comprehensively ecosystem risks and opportunities (WBCSD, 2011).

Our analysis of the chemical manufacturing industry was broken down by ecosystem service type, using the classification delineated in the MEA (2005) and elsewhere. Our analysis of the forest product industry divided current ecosystem service efforts into forestland management efforts and market-driven efforts, because most forest ecosystem projects affect more than one ecosystem service and the defining feature of forest industry efforts is whether or not they are market-based.

Step 2: Identification of Ecosystem Service Opportunities within the Two Industries

To determine the best opportunities for ecosystem service valuation in businesses, we made use of the major classes of business risk and opportunities identified in WBCSD's Guide to Corporate Ecosystem Valuation (2011), overlaying them with the main operational sectors within each business, and creating a matrix. The matrix was populated with ecosystem service management options identified through academic literature and industry literature that could potentially provide business value by managing ecosystem risks or dependencies located at that intersection (i.e., the intersection of a business risk and a business sector). This second step allowed us to identify opportunities in a structured manner. This identification will help businesses makers recognize which opportunities to target for further research and prioritization.

We then summarized the most significant opportunities, describing how they work and potential obstacles to their implementation. We illustrate the logic of this process in Figure 1.

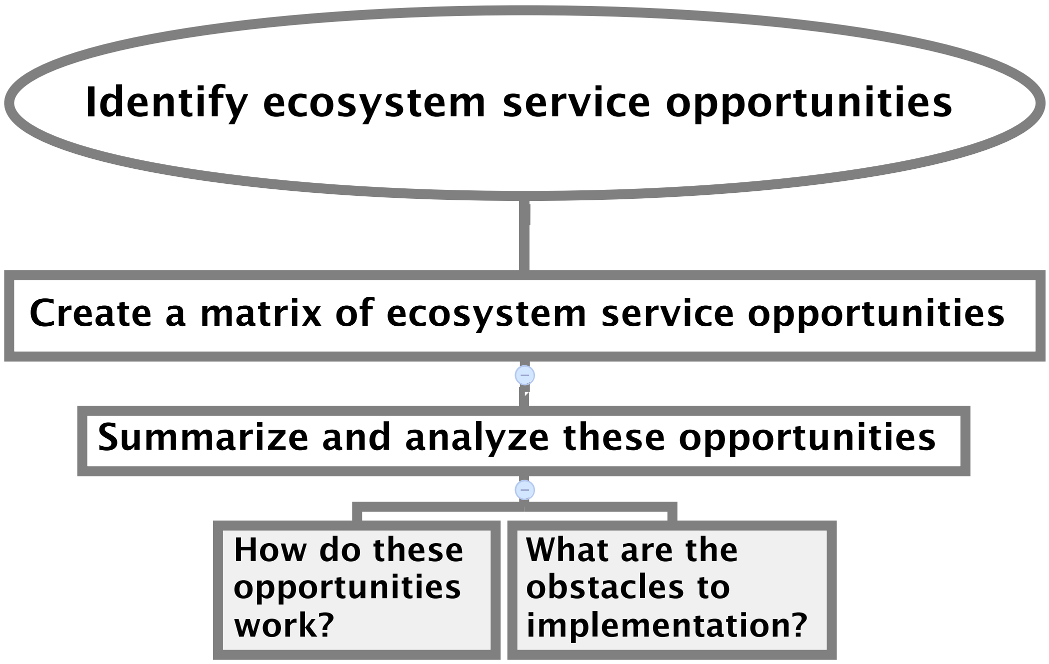

Figure 1: Logic flow to identify and describe ecosystem services opportunities.

Step 3: Prioritize of Opportunities

The third step was to evaluate the identified opportunities to determine which ones should be prioritized for investment. We developed a framework to compare these opportunities, a vital tool that managers can use to clarify their businesses' potential to benefit from ecosystem service management. The system we designed uses multi-criteria analysis (MCA) to rank the attributes of potential ecosystem service projects based on criteria most important to the company.

In order to prioritize opportunities, our system gauges five criteria critical to a project's value to a business and its ultimate development. We chose the following evaluation criteria based on discussions with TNC, as well as key business values identified in the literature on business ecosystem valuation (e.g., WBCSD, 2011; TEEB, 2012): (i) a project's financial value, (ii) the level of scientific knowledge and activity regarding such projects, (iii) the reputational benefits it offers, (iv) political and regulatory enabling conditions, and (iv) the degree to which it reduces the risk of environmental hazards. Overall, we have attempted to create an objective process for evaluating these criteria, limiting subjectivity to determining each attribute's relative importance in the particular business context. After delineating our methodology, we provide three example project evaluations, classifying each project's relative strengths and weaknesses.

3 From Sustainability to Ecosystem Service Frameworks

Businesses are beginning to account for the impacts and dependencies their operations have on ecosystems and their services. The initial corporate efforts to examine ecosystem services have varied among companies. However, the programs are typically a part of other corporate sustainability applications, ranging from large-scale corporate strategy planning to supply chain management concerns to project-level concerns, all of which rely on extant corporate structures and processes (BSR, 2013). A first step to introducing and improving ecosystem service valuation efforts and management is to consider the development of existing sustainability frameworks within the chemical manufacturing and forest products industries and the extent to which these industries are moving to models which more directly account for and value ecosystem services.

3.1 Historical Efforts to Value Ecosystem Services in the Chemical Manufacturing Industry

The chemical industry's manufacturing processes have substantial environmental impacts, which, under growing environmental and social awareness, have faced increasing public scrutiny. As such, the industry has needed to evolve with social opinion (Eccles et al., 2013; Hoffman, 1999). Many chemical companies now have elaborate environmental and corporate sustainability policies, and we identified multiple projects and potential opportunities for incorporating ecosystem services into their business operations. Despite these programs and policies, chemical companies' major sustainability efforts do not typically incorporate ecosystem service valuations. This is largely due to the primary obstacles of direct ecosystem valuation: the difficulty in quantifying regulating services and the lack of a standardized methodology for accounting for the value of ecosystems.

Since the 1960's, society has grown increasingly concerned about environmental problems caused by the chemical industry (Eccles et al., 2013). Historically, the chemical industry has been a main source of societal environmental concern due to a lack of informational transparency regarding public health and safety issues (e.g., toxic chemical releases) (Hoffman, 1999; Eccles et al., 2013). To allay these public concerns, chemical companies have begun altering business operations to reduce environmental impacts, and most companies have developed strategic goals for environmental sustainability (Eccles et al., 2013). For example, Dow Chemical established the Sustainability External Advisory Council in 1992 to bring outside voices into the decision making process to increase the informational transparency. The Council consists of external advisors including former EPA administrators and academic and business leaders (Eccles et al., 2013) and meets regularly with Dow to discuss the company's sustainability goals and procedures to realize them.

After the 1990s, chemical companies began to increase their sustainability through technological and operational improvements (Eccles et al., 2013). Aside from reducing the release of pollutants during manufacturing processes, a move necessitated by increasingly stringent government oversight, companies were more inclined to prioritize environmental issues voluntarily (OECD, 2001). For example, many companies established Environmental Health & Safety departments focusing largely on environmental issues (Dow, 2012; Eastman, 2013). Responsible Care, a global initiative for environmental health and safety improvement in the chemical industry, was founded in 1985 and is committed to achieving sustainable development in the chemical industry (ICCA, n.d.). Sustainability development in the chemical industry accelerated as a result of pressures from governmental regulation and legislation as well. For example, the Clean Air Act, which was originally passed in 1970, was revised in 1990 with the Clean Air Act Amendments .The amendment emphasized enforcement and penalties for noncompliance, with the chemical industry as the major target (Cunningham, 2001). The higher financial risk coming from the stricter regulatory oversight compelled the chemical industry to be more environmentally friendly (Cunningham, 2001; Eccles et al., 2013).

Like other industries, chemical manufacturing has increasingly developed into a global market, which makes it challenging to develop a consistent environmental management template (Eccles et al., 2013). The 2008 financial crisis compounded this difficulty, as the sector has had difficulty recovering and maintaining revenue (Jerrentrup, 2009). The primary strategy for companies to remain competitive has been through mergers and acquisitions that allow companies to reorganize resources and capital (HP News, 2013). These activities have led many once-domestic companies to enter the international market. Companies operating across international boundaries face varying regulatory constraints and ecosystem service concerns

(Eccles et al., 2013). These conditions make it difficult for companies to set clear and consistent ecosystem service goals across their operations (WRI, 2012). Although there are operational hurdles to incorporating ecosystem services into business, we are seeing a trend of increasing ecosystem service engagement in the industry.

3.2 Current Efforts to Value Ecosystem Services in the Chemical Manufacturing Industry

We reviewed major chemical companies to identify their efforts to reduce negative impacts on the environment or enhance ecosystems, specifically through their recognition of ecosystem services. TEEB defines three categories of ecosystem services relevant to the chemical manufacturing industry: regulating services, provisioning services, and cultural services (TEEB, 2012). We identified environmental sustainability efforts primarily related to reducing energy use or hazardous waste through technological improvements. Our examination found few ecosystem-oriented projects, and we observed that company reports lacked detailed information on the ecosystem-related projects they were pursuing. These results indicate that ecosystem services are still not widely recognized by the chemical industry, yet they have substantial potential to improve business sustainability (TEEB, 2012).

3.2.1 Regulating Services in the Chemical Manufacturing Industry

In the chemical industry, regulating ecosystem services are beginning to be integrated in the manufacturing process as a means of purifying wastes following production (TNC & Dow, 2012). For example, Dow has constructed an artificial wetland near its chemical plant in Seadrift, Texas, replacing wastewater management facilities with the regulatory services provided by the artificial wetlands (Dow et al., 2013). Another example of utilizing regulating services is the project Dow and TNC collaborated on in Freeport, Texas. Dow's Freeport facility is vulnerable to hurricanes due to its location —close to the Gulf of Mexico at a relatively low elevation. Although one approach to addressing this problem is to build levees to protect its facility, TNC and Dow considered restoring coastal marshes, common in the area, for the purpose of hurricane risk mitigation. In this case, the marsh provided the regulating service (TNC & Dow, 2011).

The TNC-Dow Collaboration also investigated an opportunity to reduce nitrogen oxides (NO_x) through reforestation. Nitrogen oxide gasses, precursors to smog formation, are also responsible for the development of acid rain. Currently Dow's elimination of NO_x has been achieved through conventional control methods such as scrubbers on fume stacks, an expensive but necessary business expense to comply with EPA-regulated national ambient air quality standards (NAAQS) for ozone. Future opportunities for achieving compliance may be realized through reforestation, a cost-effective method to reduce Dow's NO_x emissions within the airshed (TNC & Dow, 2012). The potential of reforestation to combat NO_x and smog has already been proven through implementation of similar projects by municipalities (Escobedo et al., 2013). Although the scale of Dow's proposed projects is small compared to the overall size of the company, these projects indicate progressive efforts to recognize ecosystem services in the chemical manufacturing sector. Our review found no other companies in the sector considering such regulating services.

3.2.2 Provisioning Services in the Chemical Manufacturing Industry

Increased concern over climate change has led organizations to seek energy sources with fewer greenhouse gas emissions (MEA, 2005). Despite this desire, only a few companies have considered timber biomass energy as a possible energy source. One of these is the Eastman Chemical Company, which has attempted to increase utilization of renewable biofuels within its business operations by 2020 (Eastman, 2013). While this project is still in the early planning stages, researchers at Eastman have completed "screening assessments of several dozen technologies and [their] supported feasibility" (Eastman, 2013). In addition, Dow and TNC, through their partnership, have investigated issues related to the availability of freshwater at Dow's Freeport chemical plant, identifying potential solutions such as wastewater reuse, sector use reallocation, land management changes, and municipal rebate programs as low-cost methods to maintain access to industrial water (TNC & Dow, 2012). These interesting initiatives, however, are outliers in the chemical manufacturing industry.

3.2.3 Reputational Benefits from Recognizing Ecosystem Services in the Chemical Manufacturing Industry

In manufacturing industries, one of the well-known benefits of recognizing ecosystem services is the ensuing enhancement of brand and corporate reputation (Corporate EcoForum and The Nature Conservancy, 2012). While this benefit is not directly derived from the natural characteristics of ecosystems, it nevertheless has become an important aspect of returns in a society with high environmental considerations (MEA, 2005; Corporate EcoForum and The Nature Conservancy, 2012). In our review, brand enhancement due to environmental and ecosystem service engagement was recognized among major chemical companies. For example, AkzoNobel, an international paints and coating company, collaborates with the Forest Stewardship Council to improve wood stewardship and improve forests' provisioning services (AkzoNobel, 2010). At the same time, AkzoNobel established educational programs highlighting the environmental advantage of their products (AkzoNobel, 2010). The collaboration between Dow Chemical Company and The Nature Conservancy is well known as one of the pioneering efforts to recognize ecosystem services-related benefits, such as waste purification and risk mitigation (Harvard Kennedy School Communications, 2013). This collaboration received a Roy Family Award for Environmental Partnership, an award presented to a significant public-private alliance to tackle environmental problems with a unique approach (Harvard Kennedy School Communications, 2013).

Despite the purported benefits and publicity given to many of these initiatives, none of the companies stated any monetary benefits that may have been derived from these ecosystem service investments. Also, the scales of these projects are extremely small relative to the size of the companies. From these observations, it is clear that reputational benefits from ecosystem service investments likely provide little monetary benefit to companies who pursue them. However, greater benefits may accrue to businesses when the full suite of ecosystem services affected by such projects is taken into account.

3.2.4 Barriers to Ecosystem Service Awareness in the Chemical Manufacturing Industry

Several barriers restrict incorporating ecosystem service with the chemical industry. From the industry's perspective, technological feasibility, cost, and risk might be the major concerns. Based on our research, we describe two main barriers, although other factors will contribute as well.

As previously stated, ecosystem services have a high potential for providing beneficial outcomes (WRI, 2012). However, this potential has almost entirely been ignored by the chemical industry. Barriers to incorporating ecosystem services into companies' business decisions are due primarily to the systemic underestimation of ecosystem service values and the difficulty of managing ecosystem services. The lack of value is one of the primary reasons for the continued loss of ecosystem services (Vihervaara et al., 2012). Although the market can effectively capture some aspects of the value of some ecosystem services, particularly provisioning services, it is difficult to express the value of regulating and cultural services in monetary terms based on the theory of externalities and market failures in environmental economics (Keohane et.al., 2007). In economics, externalities occur when one's behavior has value to society at large, but cannot be actively marketed (Thorsen, 2010). Market failure occurs when prices do not reflect the social cost of a good or service. This is common for resources that are typically not transacted in markets. For example, the value of fresh air, which is a non-market good, is difficult to value in the market. Thus, although air purification through reforestation can make society better off, it is difficult to evaluate the value of this action. Since the value of ecosystem service cannot be successfully captured by businesses, companies lack adequate incentives to make ecosystem investments. This difficulty diminishes the enthusiasm of managers when thinking about how ecosystem services benefit their companies.

Ecosystem-based technologies often require long periods of investment and development, and outcomes are less assured than traditional technologies. For example, Dow's ecosystem service pilot projects aim to enhance the functionality otherwise provided by man-made structures. However, the projects could require several years of study before implementation even begins, e.g., wetlands design or reforestation studies (Dow et al., 2013). Also, green infrastructure must fulfill various ecological requirements to achieve appropriate functionality (temperature, biotic stress, etc.), which injects more risk into the process than would a simple engineering solution (Dow et al., 2013). An example of such risk includes an outcome of lower than expected carbon storage within a forested ecosystem due to biotic or anthropological interactions (Balvanera et al., 2005; Kremen 2005). The long time period required to demonstrate the effectiveness of such programs, combined with the high variability of output quality between programs, make ecosystem service solutions less attractive for chemical companies. As we move into a discussion of the forest products industry, we see similar trends of increasing ecosystem service engagement.

3.3 Historical Sustainability Trends in the Forest Products Industry

The convergence of a broad range of trends has resulted in the growth of sustainable management in the forest products sector. These trends have been largely driven by three sets of actors: conservation interests, government interests, and profit-motivated forest landholders. Large scale deforestation in the United States' upper Midwest during the late 19^{th} and early 20^{th} centuries led to calls for forest conservation, eventually leading to the development of the US Forest Service and consolidation of most federally-owned forest lands under a single entity dedicated to preserving watersheds and promoting responsible use of timber resources. While there have been a few eras of excessive timber harvest on National Forest land, long-term sustainable harvest regimes have remained an overarching objective on federal forestlands (USFS, 1975; USFS, 2000).

While the government has a mandate to sustainably manage forests in the public interests, private forest landowners also have a rational incentive to manage sustainably. If they plan on remaining a resource-based enterprise, they have to steward their forests in a way that will provide a sustainable source of income in the future. For example, Weyerhaeuser, one of the largest private timber enterprises, recognized that sustainable forestry was critical to their business model as early as 1904, researching and investing in methods to develop timber as a sustainable crop (Weyerhaeuser, 2013a).

Internationally, the drive towards sustainable forestry has been led by conservation interests, particularly in developing countries where laws and enforcement are not as developed and sophisticated. The 1992 Earth Summit held in Rio de Janeiro provided an arena to support broad conservation efforts, leading to the development of independent certification for sustainable forest management. Since this time, a number of international nongovernmental organizations have stepped in to develop certification schemes, the most famous being the Sustainable Forestry Initiative and the Forest Stewardship Council (FSC, n.d. a; UNECE/FAO, 2012). This new brand of sustainable forestry encompasses more than simply ensuring a renewable fiber source by promoting requirements to sustain a diversity of functioning ecosystems across the landscape (Oliver, 2003). Also, these certification schemes consider the impacts of forestry not only at the site of timber growth, but through the production process and into the final products (FSC, n.d. b). In these ways, certification programs represent a pivot towards recognizing the impacts and dependencies of the forest products industry on ecosystem services. According to the United Nations, roughly 10% of the world's forests had been certified to a recognized standard by 2012, and the demand growth for certified paper products has been considerable in recent years (UNECE/FAO, 2012; RISI, 2013).

There are some challenges to incorporating broader sustainability goals within the industry. Globally, the market for forest products has been confronted with three big challenges in recent decades. These are:

- accelerated changes in the global industry due to increased international trade,
- large fluctuations in the size of the economy due to the global economic cycles, and
- institutional changes due to the disaggregation of the industrial forest estates into small, investment-oriented landholdings.

The global export value of forest products has increased tremendously in the past 15 years, largely driven by liberalization of trade policies and the growth of paper consumption in Latin America and Asia. This has led to large increases in exports from Europe to other areas of the globe. Conversely, the expansion of paper-producing capacity in Latin America has led to a slowing of pulp and paper production in the U.S. (Toppinen et al., 2010). This trend has been partially driven by Latin America's growing cultivation of rapid-growth, hybrid pine and eucalyptus species, vastly increasing its productive capacity and economic rates of return, but possibly contributing to negative ecological changes (Cubbage et al., 2009). For finished lumber and paneling, the trend has largely been the opposite of paper. In response to the housing crisis of 2008-2011, the demand for finished lumber slowed; however, this trend is expected to reverse as the domestic economy picks up. International demand for finished lumber will also increase as demand from China continues to grow, despite its slowing economy (Campbell Group, 2012). However, recent economic cycles have taken a toll on investment in the global forestry sector, as perceived financial risk in the sector has increased while returns have stagnated (FAO, 2011). These macroeconomic trends may have increased the attractiveness of sustainable forest certification, which increases access to markets, but their effect on ecosystem service valuation is uncertain (FAO, 2009; Chen et al., 2010). Most firms will likely need to see proven returns from ecosystem service investments before they begin to account for their values.

Within the U.S., the last two decades have seen a remarkable transition in investment and management in the U.S. forest products sector (Bliss et al., 2008). Traditionally, the sector was organized into vertically integrated forest-product companies that owned and managed timberland, organized the logging crews, controlled the processing capacity, and marketed goods all the way downstream to the end consumer. This model has all but disappeared from the landscape, as the sector has seen wide-scale disinvestment by the traditional industrial forestland owners. In their place, a new class of timberland ownership in the form of Real Estate Investment Trusts (REITs) and Timberland Investment Management Organizations (TIMOs) has arisen. These new timberland owners, largely comprised of institutional investors, are now attempting to derive additional profit from the land by obtaining rents from the management of the forests' productive capital (Bliss et al., 2008; Campbell Group, 2006a).

To underscore the magnitude of this change in the U.S., between 2002 and 2007 nearly 26 million acres of forestlands switched hands (based on an analysis of land sales greater than100,000 acres (Bliss et al., 2008). Transferred lands went from being controlled by 21 timber products companies to over 37 smaller TIMOs and REITs (Bliss et al., 2008). This transition has significantly transformed the suite of objectives under which forestland is managed, altering time horizons and management capacities. The funds developed by these organizations are typically of a fixed length (e.g., 15 to 20 years), and their returns are determined by incremental harvests, land value appreciation, and real estate development. At the end of the investment periods, the remaining lands may be liquidated or transferred to another fund (Block & Sample, 2001; Bliss et al., 2008). These relatively short investment time horizons may be misaligned with the long time frames needed to reap benefits from ecosystem service investments. On the other hand, these investment firms have proven to be willing to invest in forest certification, due both to the broader access to markets it provides, and to the socially responsible image it projects to potential investors (Chen et al., 2010). This participation in sustainable certification schemes may indicate a willingness to engage in ecosystem service valuation if the benefits could be adequately demonstrated.

On the processing side, disinvestment from the land base has led to the closure of many mills across the country (Campbell Group, 2006b). This has had the negative effect of restricting markets for many of the smaller-scale landowners who traditionally depended on small local mills for processing. Small-scale mills remaining in operation do so in a climate of increasingly stringent environmental regulation, which increases their costs of doing business (Bliss et al., 2008). While the large paper product companies largely disinvested in timberland holdings, consolidation in the processing side has proceeded slowly, with little change to the market share of the ten largest forest product firms over the past decade (Toppinen et al., 2010).

The remaining processing plants have benefited from a few trends on the demand side. The ability to source sustainable feedstock and sell sustainable product has provided some additional revenues, especially for paper products manufacturers (Schreiber, 2012). Increased demand for biofuels has provided firms in the southeastern U.S. access to a new export opportunity to Europe (Vihervaara, 2010). In all, the past few decades have seen rapid changes in management and ownership of forestlands both within the U.S. and internationally. The historical growth of certification indicates a general willingness, if not a need, to invest in schemes to protect the value of ecosystems. Also, past fluctuations in demand have increased the need for forest product companies to seek new opportunities in order to stabilize revenues over the long term.

3.4 Current Efforts to Value Ecosystem Services in the Forest Products Industry

Forest product companies have abundant opportunities for ecosystem investment due to their intense interactions with the landscape required for forestland management. Moreover, there are a number of outside factors increasing companies' appreciation for the ecosystem services that their operations rely on. These factors include climate change, population growth, and increasing demand for energy and water. These trends are leading many companies to realize the potential of forests to provide a range of renewable goods and services. Recently, many forest product companies have begun to expand their business models, investing in ecosystems to protect their long-term business interests. Under this new model these companies have increased opportunities to generate income from ecosystem services-derived benefits. Such opportunities include carbon storage, wildlife preservation, recreation provision and watershed protection.

3.4.1 Forest Land Management Efforts to Develop Ecosystem Services

Currently, forest product companies such as Mead Westvaco, Weyerhauser, Fibria, Sveaskog, Plum Creek, and Mondi have valued forest ecosystem services in their business decision-making models in some capacity, with some even developing ecosystem service-based products or services (e.g., BSR, 2013; Mondi Group, 2011). Examining operational decisions among these companies reveals a sector-specific focus to ecosystem investment, aimed at such business divisions as real estate management, forest operations, and overall corporate performance. In their land management programs, they have classified land zones and prioritized allocation of resources, based on efficiency, in order to maximize profit (USDA, 2005). For example, Mead Westvaco is trying to prioritize and manage different primary ecosystem services within the zones that it operates (Cooke, 2013). Specifically, Westvaco has expressed preference for purchasing wood certified by the American Tree Farm System. This system provides landowners with sustainable harvest practices without degrading habitat, thus buying certified wood from these landowners is considered to be a sustainable approach (Cook, 2013).

As another example, Weyerhaeuser measured and reported 18 separate functions that forest ecosystems provide (Weyerhaeuser, 2013d). By measuring the individual services and reporting them annually, Weyerhaeuser has been able to gain valuable insight into the benefits provided by its landholdings and is able to communicate this value to customers and stakeholders. Weyerhaeuser has even started a consulting company named Weyerhaeuser Solutions to help other landowners manage for ecosystem services and other environmental benefits (Weyerhaeuser, 2013b, d). Fibria has developed ecosystem services valuation tools for use in its decision-making procedures as a way to enhance its business model. They have indicated that the use of these valuation tools enables them to better account for the value ecosystems have within their operations and target the best candidates for restoration investments (WBCSD, 2012).

3.4.2 Market Driven Efforts to Develop Forest Ecosystem Services

Sveaskog, Sweden's largest forest owner and forest products manufacturer, now derives approximately 15% of annual net sales from biomass for energy and nontimber services (Persson & Ranganathan, 2011). Their efforts at managing ecosystem values include the issuance of hunting and fishing licenses, establishment of recreation fees, and the development of conservation easements. In addition, Sveaskog indicates that it currently manages one-fifth of its land for conservation and promotion of biodiversity (Persson & Ranganathan, 2011). Sveaskog is also experimenting with how to maximize a forest's carbon sequestration rate through different management techniques and plans to market carbon within the Union Emission Trading Scheme. Sveaskog hopes to double its current revenue from biomass and different kinds of non-timber services over the next two decades (Persson & Ranganathan, 2011). Plum Creek, the largest US private landowner, is similarly shifting focus to incorporate the value of ecosystem services for their operation (Persson & Ranganthan, 2011). Plum Creek currently devotes about a third of the company's seven million acres of timberlands to revenue-generating conservation and wildlife protection agreements (Persson & Ranganathan, 2011).

One provisioning environmental service that has seen significant growth in value is the market for wood pellets derived from harvest and wood-processing residual materials. Over the last five years, the wood pellet market has grown more than 110%, from an estimated 6-7 million tons in 2006 to 14.3 million tons in 2010 (IEA Bioenergy, 2011). This dramatic increase in demand for industrial wood pellets is driven primarily by countries within the European Union, which incentivized the use of bioenergy through the development of its multi-national carbon emission trading scheme (Siceloff, 2013). In 2010, the EU consumed 11.4 million tons of industrial wood pellets, nearly 85% of the global wood pellet supply (IEA Bioenergy, 2011). Given the EU's regulatory framework, co-firing wood products with fossil fuels has become relatively competitive with traditional energy sources. While the prospect for future growth in the wood pellet market is positive, it relies heavily on the continuity of the supporting policies. Due to the projected growth in wood pellet demand, there will be an even greater need for a stable and secure supply of feedstock. While forest product companies will be happy to benefit from this new revenue-making opportunity, the practice has been criticized as endangering the sustainability of southeastern forest management (Siceloff, 2013).

It is not just large forest products companies that are interested in reaping the benefits from ecosystem service management on their lands. The large amount of land that has traded hands in the last two decades has afforded conservation buyers and smaller landholders opportunities to acquire easements and fee simple ownership on large tracts of forestland (Binkley, 2008; Bliss et al., 2008). These classes of ownership may be more willing to engage in inventive forestry practices designed to enhance provision of ecosystem services, perhaps providing ancillary income to their forest management practices. For instance, the Pacific Forest Trust has developed forest carbon management projects that are resulting in the sale of forest carbon credits into the California market under its regulatory cap and trade program (Pacific Forest Trust, 2013). As some of the larger players see the success that the smaller groups have experienced, it is possible that they will begin to increase participation, as the risks to participation become better defined. In fact, the Potlatch Corporation, a large forest Real Estate Investment Trust, registered one of the largest California-eligible forest carbon projects, at over 15,000 acres (Finite Carbon, 2013).

In summary, these forest product companies are increasingly recognizing ecosystem services that forests provide and are actively considering these benefits in their business decisions. Stakeholder engagement through websites, company journals, reports and public projects are becoming popular in promoting their reputation to the public. By communicating the recognition of ecosystem services at the company level, managers are able to attribute more reputational value to their products.

3.4.3 Barriers to Ecosystem Service Awareness in the Forest Products Industry

As is the case with chemical manufacturing, the failure to achieve large-scale investment in ecosystems within the forest products industry partially results from unpriced externalities in the market for forest products. For example, in the forest product industry, biodiversity maintenance, erosion protection, recreation provision, and air quality regulation—ecosystem services whose value is difficult to assess and market -- are non-marketed goods. Without an active market, it is difficult to promote investment in and maintenance of intact ecosystems, so forest product companies have little incentive to do so. Additionally, evaluation of forest ecosystem services is difficult since the spatial scales at which the services and investment occur are typically local, while the benefits they yield are often regional or global. For example, investment in carbon sequestration occurs at the level of the forest, but the climate change mitigation benefit it provides is global. Programs such as the NEWFOREX project (New Ways to Value and Market Forest Externalities) have arisen to address this issue and develop new ways to enhance the recognition of provisioning forest goods and services (NEWFOREX, 2013).

According to Goran Persson, the chairman of Sveaskog and former Prime Minister of Sweden, there are four major market changes keeping companies in the forest product industry from realizing potential advantages to investing in ecosystems. First, there must be significantly more involvement from industry leaders who can provide clear examples of financial gain before other companies take action. Second, there must be explicit governmental recognition of the ecosystem services that forests provide (water regulation, carbon sequestration, air quality, etc.). Third, to accomplish an industry-wide transformation within the forest product sector, governments must adopt policies that put monetary value on ecosystem services. Finally, governments must put a particular focus on developing pricing strategies for carbon, as has started to occur with climate mitigation strategies. Should these four conditions be achieved over the next decade, significant transformation of the forestry product industry may occur (Persson & Ranganathan, 2011). With new markets emerging for companies to take advantage of, investment diversification is likely, particularly in the type and size of forest ecosystems.

3.5 Overall Discussion of Trend Analysis

Our analysis found an increasing focus by the chemical manufacturing and forest product industries on how they interact with the surrounding environments. As public interest in environmental issues such as energy efficiency and resource depletion has grown, companies have extended their attention from environmental health and safety issues to sustainable business practices (Eccles et al, 2013). This trend has been followed by an emerging attention to ecosystem services, whereby companies not only protect the environment but find ways to benefit from their environmental investments (MEA, 2005). Among the four different types of ecosystem services, our analysis showed that the most common ones considered by the chemical and forest product industries were regulating and provisioning services. Interest within the chemical manufacturing industries tends to focus on waste management, while the forest industry tries to incorporate a broader range of ecosystem services through the establishment of ecosystem service markets.

Despite these trends, several challenges impede industries' efforts to invest in this new field. Perhaps the greatest obstacle is the difficulty businesses have in recognizing the potential opportunities. Ecosystem services are a relatively new field, and not many companies have systems in place to recognize potential ecosystem-related opportunities. Organizations like TEEB and the WBCSD are attempting to bridge this gap, but their solutions are largely untested in applied settings. Furthermore, they are mainly focused on helping organizations recognize the extent of their ecosystem impacts and dependencies, and do not provide tools for prioritizing potential investments in ecosystem service-based projects. In the next section, we identify potential ecosystem-related risks and opportunities specific to the chemical manufacturing and forest products industries through an adaptation of the TEEB/WBCSD process. Section 5 presents a novel approach for businesses to prioritize investment in identified ecosystem service opportunities. These sections demonstrate both what the real-world application of the TEEB/WBCSD process may look like and how businesses can move from identifying opportunities to prioritizing and potentially investing in them.

4 Identifying Ecosystem Service Opportunities in Business

In this section, we identify potential ecosystem related risks and opportunities specific to the chemical manufacturing and forest products industries. In section 5, we present a prioritization of selected opportunities. Identifying opportunities is a process organizations would undertake using either their own expertise to brainstorm potential risks and opportunities or employing environmental sustainability consultants familiar with the business's operations.

We use a structured process to uncover potential ecosystem risks and opportunities within our industries of interest, largely adapting an approach identified by the WBCSD and used by TEEB to identify ecosystem risks across sectors (WBCSD, 2011; TEEB 2012). There are two primary differences between TEEB's application and our own. The first is that TEEB's application looks broadly at risk across sectors, while ours focuses on the risks within one sector or business. Secondly, because our process is undertaken within one sector we can identify specific risks or opportunities as well as projects that can address them; TEEB's process only identifies the presence or absence of specific types of risk in various sectors (TEEB, 2012). We developed our matrices separately for the chemical manufacturing and forest products industries, as described below. The process can easily be replicated across a number of industries.

In order to develop a list of ecosystem service opportunities best suited for the industries being examined, we constructed matrices in which major classes of business risk and opportunity recognized in the WBCSD's Guide to Ecosystem Valuation—operational, regulatory, reputational, market (WBCSD, 2011)—were overlaid on major industry subsectors as identified through our review of industry sources. At the intersection of the business sectors and risk/opportunity factors, we place relevant ecosystem service risks, opportunities and associated projects that arise at these intersections. The major classes of business opportunity and risk should be static across industries, but they can be broken down into subsections unique to the particular sector. For example, a manufacturing company might break regulatory risks and opportunities into various types of pollution (e.g., air, water, and soil), while an accounting organization may be more focused on regulations pertaining to record keeping and reporting (e.g., records retention and materiality thresholds). Business industry subsectors are also necessarily industry dependent. Given the wide scope of operations and product lines found in the chemical manufacturing industry, we defined the sectors by function as opposed to business division, demonstrating the method's flexibility. These functions are real estate, production, and site infrastructure. From our literature review, we identified the major subsectors of the wood products industry as real estate, timber management, pulp and paper, and wood products.

While a business going through this process would fill out the matrix based on their unique knowledge of their own business practices, we have had to rely on risks, opportunities and example projects gleaned from our literature review. Ecosystem service risks and opportunities may be put into more than one cell, perhaps indicating a risk or opportunity of greater magnitude. For example, we determined that paper mills require a lot of water and can have pollutants in their water effluents. These pollutants and their ecosystem impacts present a major regulatory risk for the paper industry (EPA, 1977). However, we also identified an ecosystem-related opportunity related to effluent treatment, whereby the effluent is diverted into manmade wetlands for treatment prior to release into waterways (Choudhary et al. 2011). These are just two examples of the risks and opportunities identified using this matrix-based process.

Below, we present the matrices we developed for the chemical manufacturing and forest products industries (Tables 2 and 3). The headings along the top represent subsectors within the industry, while those along the side are specific classes of ecosystem risk and opportunity. At the intersections are various risks, opportunities and projects we identified through our literature search that have relevance at these intersections. These items are numbered in the matrices, with the keys below the matrix naming the risk, opportunity or project identified. Following the matrices, we give in-depth descriptions of several key project types within the chemical and forest products industries that we identified through our literature review as being particularly promising or well-researched (Section 4.3). Brief descriptions of the remaining risks, opportunities, projects and their associated sources can be found in the Appendix (Tables 27 and 28).

4.1 Risk and Opportunity Identification Matrix for the Chemical Manufacturing Industry

The matrix in Table 2 below identifies possible interactions between the chemical industry and surrounding ecosystems. A description of each risk and opportunity is provided in the Appendix. Selected opportunities are further described in Section 4.3.

Table 2: Matrix depicting ecosystem service risks and opportunities in the chemical manufacturing industry.

Chemical Manufacturing Industry

		Business Sector		
		Real estate	**Production**	**Site infrastructure**
Category of risk or opportunity	**Operational**			
	Scarcity & cost of raw materials	6,11	6,11	
	Natural hazard	4	4,10	10
	Water provisioning		1	
	Regulatory			
	Air pollution	2, 3	1, 2, 3, 13	
	Water pollution	4, 5, 7	1, 4, 5, 7, 14	4
	Soil pollution	7, 8	7, 8, 9	
	Noise reduction	19	19	19
	Reputational			
	Corporate image		10, 16, 17, 18	
	Brand equity		10, 15	
	Market			
	New product or technology		12	

Table 2a: Key for risks and opportunities identified in the chemical manufacturing industry matrix.

Category	Project ID	Specific Risk or Opportunity
Air Quality and Climate	1	Reforestation air quality benefits
	2	Release of greenhouse gases
	3	Release of toxic gases
Water	4	Constructed wetlands for purification
	5	Eutrophication
	6	Freshwater scarcity
	7	Release of water pollutants
Soil	8	Phytoremediation, a soil mitigation approach
	9	Synthetic polymers technology for soil mitigation
Conservation	10	Habitat conservation
Market	11	Energy price
	12	Renewable chemical market
Regulation	13	Clean Air Act
	14	Clean Water Act
Other	15	Brand equity as a reputational benefit
	16	Cooperation with environmental organizations
	17	Environmental catastrophes
	18	Responsible Care, an organization for sustainability
	19	Vegetative buffers for noise mitigation

4.2 Risk and Opportunity Identification Matrix for the Forest Products Industry

The matrix in Table 3 below identifies possible interactions between the forest products industry and surrounding ecosystems. A description of each risk and opportunity is provided in the Appendix. Selected opportunities are further described in Section 4.3.

Table 3: Matrix depicting ecosystem risks and opportunities in the forest products industry.

Forest Product Industry

Category of risk or opportunity		Business sector: Real Estate	Timber Management	Pulp & Paper	Wood Products
	Operational				
	Scarcity & cost of raw materials	10, 11, 23, 24, 25	2, 3, 4, 5, 10, 11, 12, 16, 17, 21, 23, 25	2, 3, 4, 5, 11, 16, 17, 23	2, 3, 4, 5, 11, 16, 17, 23
	Natural hazard	2, 4, 6, 11	2, 3, 4, 6, 12	2, 3, 4, 13, 14	2, 3, 4, 13, 14
	Regulatory				
	Air pollution		1, 6, 18		
	Forest protection	22, 24	2, 3, 6, 10, 18, 21, 22, 28		2, 8, 17, 28
	Water regulations		19, 20, 21	7, 8, 20	20
	Wildlife	2, 15, 22, 24	3, 12, 15, 21, 22	7, 9	
	Reputational				
	Corporate Image	24	1, 2, 10, 11, 12, 15, 28	7, 8	17, 28
	Market				
	New product or technology		13, 15, 19, 26	7, 8	13, 17
	Environmental commodity		3, 10, 11, 14, 26		27

Table 3a: Key for risks and opportunities identified in the forest products industry matrix.

Category	Project ID	Specific Risk or Opportunity
Air Quality and Climate	1	Air quality benefits
	2	Bark beetle outbreaks due to climate change
	3	Changing species ranges due to warm temperature
	4	Climate change
	5	Climate-driven growth effects on trees
	6	Fire risks caused by climate change and human impacts
Water	7	Constructed wetlands for water purification
	8	Release of water pollutants
Soil	9	Soil nutrient depletion by removing wood residuals from forests
Conservation	10	Competition between forest product firms and conservation groups
	11	Conservation easements (forest owners sell certain development rights)
	12	Endangered species act/species management
	13	New genotypes (rapid growth, disease resistant)
	14	Wood disease spread (frequent occurrences of natural hazards)
Market	15	Biodiversity markets (compensatory mitigation and conservation banking)
	16	Bioenergy demand effects on wood price
	17	Forest biofuel demand and effects
	18	Forest carbon markets
	19	Water quality markets
Regulation	20	Clean Water Act (erosion/runoff)
	21	Federal & state forest practice guidelines/ increased regulation
Other	22	Competition between forest conservation initiatives and agricultural activity
	23	Competition with other operational segments (real estate) within one firm
	24	Conversion of agricultural lands to forests
	25	Land quality/price relationship
	26	Recreation permits (hiking, hunting & fishing)
	27	Responsible development/community involvement
	28	Sustainable certification for reputational benefits

4.3 Matrix Interpretation and Identifying Key Opportunities

Through the matrix development process we identified numerous risks, opportunities and potential projects. While there are other methods for generating such a list, businesses are already familiar with this matrix model, as it mimics standard, commonly used risk management frameworks (TEEB, 2012). This structured matrix process allows managers to focus on specific business/risk interactions pertaining to ecosystems, as opposed to a more free-form process where decision makers may not recognize the ways a particular risk or opportunity affects their businesses. By counting the number of times related risks, opportunities, and potential projects appear in the matrix, managers can gain insight into the potential impact such a risk or opportunity may have on their organizations.

We noted on the chemical industry matrix that the greatest number of risks and opportunities were related to water (13 times), followed by air and climate related issues (7), habitat conservation (4), soils (3), and noise (3). For the forest products firms, both conservation and climate and air quality were highly represented (30+ interactions each), followed by water quality (13), and forest bioenergy (9). Given the magnitude of these impacts, we decided to focus further examination on potential ecosystem service projects identified in these areas, We describe the process for ranking the potential business value of these selections in Section 5.

4.3.1 Air Pollution Mitigation through Forests

Many chemical manufacturing processes create gaseous pollutants such as sulfur dioxide (SO_2), ammonia, greenhouse gases (carbon dioxide, nitrous oxide, and methane), and ozone precursors (Cefic, 2011). The EPA's Toxic Release Inventory (TRI) shows that chemical manufacturing also releases other toxic substances such as chlorine, sodium nitrate, and even metal compounds: zinc, lead, mercury and cadmium (TRI, 2011). Although the total amount of airborne toxins has decreased significantly since 2003, the chemical manufacturing industry accounts for more than one third of air pollutants (EPA, 2011b). In addition to airborne toxins, the EPA now regulates greenhouse gas emissions. In 2010, the EPA established a guide requiring select facilities to obtain greenhouse gas emission permits. The regulations classify nitric acid plants as one of the five industries with the highest greenhouse gas emissions (EPA, 2010a). These regulations have a large effect on the chemical industry because nitric acids are commonly used in fertilizer production (EPA, 2010b). The EPA now encourages facilities to plant trees to meet air quality standards (EPA, 2004b).

Forested ecosystems have the ability to remove numerous types of air pollutants (MEA, 2005; Dow & TNC, 2011; Li et al., 2003). It is well known that forests mitigate global warming by taking up greenhouse gases (MEA, 2005). Trees, like all plants, take up the greenhouse gas carbon dioxide (CO_2) from the atmosphere to meet both their energy and structural requirements. Trees' structural components, such as the roots, boles, and branches, can store this carbon for decades or even centuries if undisturbed. Harvesting for the purposes of developing forest products releases much of the stored forest carbon into the atmosphere, where it can persist and exacerbate the effects of climate change (Dixon et al. 1994; Winjum et al., 1998). Companies in the forest product industry have potentially lucrative opportunities for managing existing lands for greater carbon retention and climate mitigation, as well as afforesting lands at the regional level, if compensated for their efforts through carbon trading programs such as California's compliance carbon permitting system (Cal EPA, 2011b).

Studies show that reducing harvest frequency and practicing structural retention (i.e., leaving a certain number of trees standing post-harvest) significantly increase the amount of carbon stored on site over time when compared with traditional short-rotation clear-cut techniques (Nunery & Keaton 2010; Harmon & Marks 2002). Additionally, engaging in reforestation of cut-over areas or afforestation of non-forested areas has carbon and climate benefits. These practices extend the opportunity for participation in forestland carbon sequestration beyond current participants to include holders of marginal agricultural lands (Michetti & Rosa, 2012). Engaging in these projects requires trade-offs, as they often impact the amount of timber available for extraction, but compensation mechanisms, such as carbon trading programs in California, may make it beneficial for some participants. In fact, firms have already enrolled hundreds of thousands of timberland acres in carbon sequestration programs for California and British Columbia (Finite Carbon, 2013; Forest Land Group. 2013).

The capacity of urban forests to regulate air pollution has also been shown to be both real and cost-effective. For instance, Escebedo et al. (2008) analyzed the effectiveness of a program in Santiago, Chile, designed to address the city's particulate matter problem, focusing on particulates less than 10 µm (PM_{10}). They found that the program, which increased municipal budget allocation to municipal forests, contributed to the average removal of 7.5 – 8 $g/m^2/yr$ of PM_{10} across the city at an average cost of $7,800 – $11,100 USD/ton PM_{10}. This compares to an average price of $25,000/ton PM_{10} removed under other abatement strategies in the city, such as vehicular regulation and compressed natural gas conversion (Escebedo et al., 2008). In TNC's collaboration with Dow, the benefits of improving air quality through urban forestry include the removal of nitrogen oxides (ozone and smog precursors), sulfuric oxides, and carbon monoxides (Dow & TNC, 2011). Another study in China found that trees are capable of absorbing pollution elements such as sulfur, chlorine, zinc, copper, and lead (Li et al., 2013). Further studies have shown that tree leaves can retain particulate matter and heavy metals such as cadmium and chromium (Qui et al., 2009).

EPA standards require that reduction of air pollutants be quantifiable, additional, enforceable, and permanent (Dow & TNC, 2011). Furthermore, it is not the EPA itself that must create and administer novel schemes to reduce criteria air pollutants but rather the states through their own implementation plans. To our knowledge, reforestation measures for NO_x reduction have not been approved in any jurisdiction. This is likely because the requirements are difficult to satisfy via ecosystem-based approaches due to natural uncertainties (Dow & TNC, 2011). For example, the amount and types of air pollutants that can be processed vary greatly among tree species (Li et al., 2003; Qui et al., 2009). Another concern is the time necessary to establish and maintain a forest until it can adequately moderate air pollution, at least three to four years (Cal EPA, 2011a). The long development time and natural uncertainties make it difficult to estimate the initial and ongoing costs of a reforestation project. As a result, we suggest that businesses refrain from entirely replacing current technologies with forest based approaches to remove their air pollutants. Instead, they should adopt a hybrid of engineering and ecological approaches to increase the predictability of air pollutant removals.

Although the potential for participation in forest carbon offset schemes is high, it is not without its barriers and obstacles. For one, there are the trade-offs between the rate of timber production and the quantity of carbon sequestered. Additionally, participants must develop substantial knowledge in order to create and carry out forest management plans that meet the rigorous standards set forth in carbon trading programs. All of this can be costly in the near term, with up-front costs that may not be recovered for four to five years (Galik et al., 2009). Given the time value of money (i.e., the rate of return from private investment), the cost profile of a project may significantly erode or ultimately negate the financial benefits possible. Alternatively, such factors may restrict participation to only the largest landholders, who can rely on economies of scale.

In addition to the entry and financial barriers, forest carbon sequestration projects rely on government policies such as California's Global Warming Solutions Act (State of California, 2006) and British Columbia's Greenhouse Gas Reduction Targets Act (Queen's Printer, 2014) to be financially viable. These laws, and the regulations that support them, define the eligibility of forestlands to participate in carbon trading schemes. They also restrict the applicable jurisdiction and are subject to alteration or nullification based on the prevailing political climate. However, successful implementation of these programs may lead other jurisdictions to follow suit and strengthen the political resolve to maintain them.

4.3.2 Water Pollution Mitigation through Constructed Wetlands

The chemical manufacturing and forest product industries generate significant water pollutants. Specifically, the manufacturing of chemical, pulp, and paper products can produce harmful, regulated pollutants such as absorbable organic halides and chlorophenolics, toxins that affect biological oxygen demand and require costly compliance measures. The chemical industry has also been responsible for significant chemical discharges and hazardous waste sites that pollute watersheds and affect drinking water and aquatic organisms (EWG, 2009). Additional pollutants from both industries include organic chemicals, as well as nutrients and metal compounds (EPA, 2009; TRI, 2011). Organic chemicals discharged directly from chemical factories include carbon tetrachloride, chlorobenzene, dichlorobenzene, adipate and phthalate (EPA, 2009). Chlorobenzene, an organic solvent and pesticide constituent, persists in waterways, building up in aquatic organisms through bioaccumulation. Human exposure to chlorobenzene can lead to kidney and liver problems (EPA, 2013a). Nutrients such as nitrogen and phosphorus come from fertilizer production (EPA, 2009). When present in high concentrations in waterways, these nutrients can lead to eutrophication and produce algal blooms that lower oxygen levels in aquatic systems to the point of asphyxiation for many aquatic organisms (USGS, 2013). Other common hazardous pollutants from the chemical industry are metal compounds, such as zinc and lead (TRI, 2011). In drinking water, high levels of lead are fatal, and even trace levels can cause the delay of mental and physical development for children and blood pressure disorders for adults (EPA, 2013c).

Scientists have long recognized the role of wetlands as natural water filters. Recently, businesses have been encouraged to use constructed wetlands as water purification systems (EPA, 2004a; Verhoeven, 1999). In a wetland, water, soil, vegetation and organisms interact systematically. Wetlands slow water flow, allowing suspended material to precipitate out of the water column. As the water slows, plants also have more opportunities to take up pollutants, as do microorganisms, which can degrade and transform pollutants into less available forms (EPA, 2004a). Microorganisms in wetland soils remove excess nitrogen through nitrification and subsequent de-nitrification and can transform organic nitrogen into nitrate and ammonium, both subsequently absorbed by soil (Vymazal, 2010; EPA, 2004a). Research also shows that metals are removed by combined physical, chemical and biological reactions in the wetlands, including sedimentation, complexation, plant uptake, oxidation and reduction. For example, copper and zinc can be absorbed and concentrated in manganese oxides and iron oxide occurring in wetland sediments (Dunbabin et al., 1990). Aside from their water purification capacities, wetlands can also provide wildlife habitat and recreational opportunities (EPA, 1993). These co-benefits can help generate an environmentally friendly corporate image.

Since the 1950s, scientists have successfully designed artificial wetland systems to mimic natural processes (Vymazal 2010). Designs for these systems include free water, vertical, and horizontal treatment options. Free water systems impound water in a shallow, constructed basin and use plantings of specialized macrophytic plants to remove suspended solids and to metabolize nutrients aerobically and anaerobically. Figure 2 illustrates the elements of a constructed wetland and how different species of plants work collaboratively to purify effluent. Vertical and horizontal flow systems are designed to release water into wetland soils, with differing anaerobic and aerobic outcomes. The various types of constructed wetland systems can be combined into a comprehensive system, which is sized based according to the volume of waste and the necessary retention time to reach the desired pollution abatement level (Vymazal 2010). Research has shown that such constructed wetlands are highly efficient for removing suspended solids and biological and chemical oxygen demand, but are less effective for addressing nutrient loads (Verhoeven et. al., 1999; Scholz, 2011).

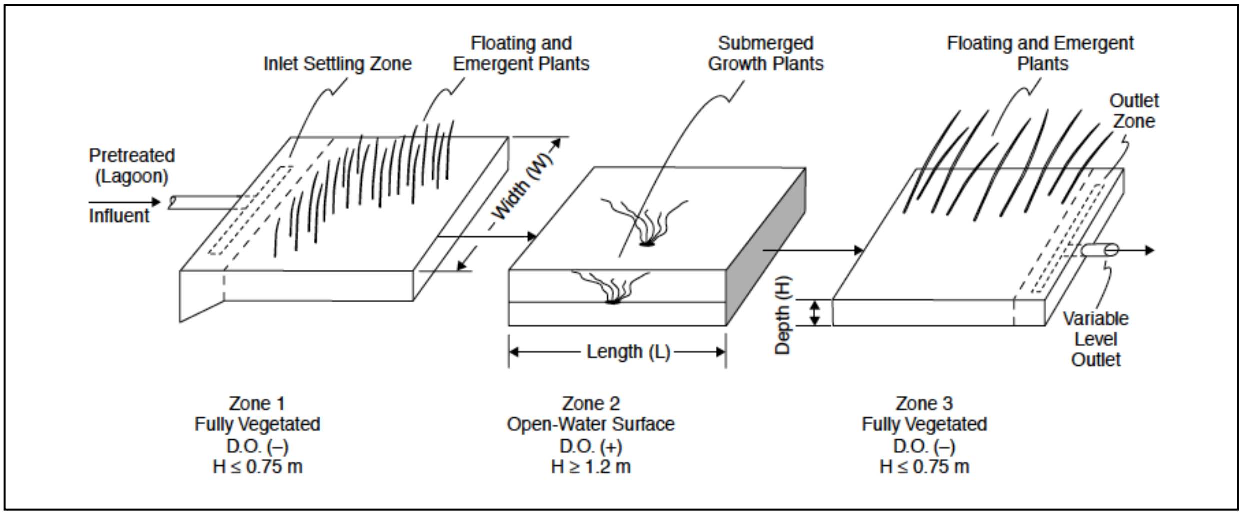

Figure 2: The elements of a surface constructed wetland (EPA, 2000).

The EPA's database currently lists over 350 constructed wetlands operating in the US for waste treatment purposes. This list includes more than a dozen constructed wetland sites designed for industrial wastewater management, including chemical and paper mill wastewaters. However, most are pilot-scale systems (EPA, 2000). Although wetland systems are often less costly to construct than comparable engineering solutions and are less energy-intensive to run, the high concentration of pollutants in many industrial wastewaters may necessitate treatment prior to discharge into a wetland, reducing this method's cost-effectiveness (Scholz 2011; ITRC 2003). Construction of artificial wetlands, which can be used for biological treatment of effluents before reusing it or returning water to streams, may provide opportunities for paper manufacturing plants to achieve a lower cost method to meet water regulations (Choudhary et al. 2011). In the U.S., artificial wetlands have been used primarily to treat municipal wastewater (EPA, 2004a), but a number of pilot studies and industrial-scale projects at paper plants worldwide indicate that the methods can also be applied successfully in industrial contexts (Vymazal, 2010; EPA, 2000).

While the science is well developed, barriers remain for relying on this approach for facility-wide treatment. These include the costs to design and maintain such a system and the need to retain qualified personnel to design and manage it to a high standard of effectiveness. Although regulatory agencies are typically enthusiastic about this practice of waste treatment, there is significant risk because such systems sometimes fail to meet regulatory discharge requirements (ITRC, 2003). Constructed wetlands are also subject to fluctuations in efficiency based on natural factors, such as temperature, pH, and the concentration of nitrogen. Therefore, it is imperative to design such systems in consultation with regulatory agencies. Additional mitigation efforts may be necessary if the constructed wetlands fail to sufficiently reduce the pollutant. (ITRC, 2003).

4.3.3 Water Pollution Mitigation through Forestlands

The U.S. Forest Service estimates that roughly 50 percent of our freshwater supply originates in forests (USFS, 2010). Considering that 60 percent of the nation's forests are privately owned, private forest owners have a disproportionate influence on the national supply of water, representing an opportunity to engage in management for water quality purposes (USFS, 2007). The EPA supports the development of water quality trading mechanisms to manage water pollution loads under the Clean Water Act, but, to date, water trading markets have only been established in a handful of jurisdictions (EPA, 2008). With adequate engagement and support from forestland and industrial stakeholders, the expansion of these markets to widely incorporate forestlands can mutually benefit stakeholders and the environment.

The role of forests in the hydrologic cycle is well documented; likewise, so are the potentially negative water quality outcomes of intensive forestry. Forests facilitate infiltration of precipitation into groundwater catchments, prevent erosion by anchoring the soils and slowing overland flows, shade forest soils from desiccation, and filter pollutants from agricultural and urban runoff (IUFRO, 2007). On the other hand, felling trees in steep catchments, improper road construction, and failure to properly re-vegetate felled forest stands can result in extreme spikes in stream flows, nutrient runoff, erosion, and water turbidity (Likens et al., 1970; Swank et al. 1982; Swift, 1985). The federal government and a number of states have crafted regulations and Best Management Practices to reduce the magnitude of these impacts on private and public lands, but the rigor and enforcement of these standards is mixed (Ellefson et al., 2004).

For forested lands, the ability to participate in water quality trading is mostly tied to the surface water quality needs of drinking water treatment facilities. In watersheds with high turbidity and sediment loads, treatment facilities remove the sediments, often returning them to source streams—a problematic practice from a pollution discharge-permitting standpoint. In such instances, the treatment facility may be able to pay upstream forest landholders to establish or expand riparian buffers, reducing their contributions to surface runoff and turbidity. This credit for lowering stream sediment and turbidity is applied against the treatment plants' point source pollution obligations, in effect decreasing the level of treatment required by the plant prior to releasing effluents into public waterways. To be creditable, baseline rates of erosion and sedimentation, as determined from allowable loads in the absence of trading, are compared to the modeled, estimated, or measured effect of a new best management practice (EPA, 2007).

While there is ample opportunity for growth in water quality trading in the U.S., it is not without obstacles. Federal law provides for the possibility of water quality trading to meet certain requirements set by the Clean Water Act, but trading schemes are regional and lack uniformity overall. Trading works much better when it occurs on waterways with significantly stringent Total Maximum Daily Loads (TMDLs) for the traded pollutants, but not all waterways have these levels established. Similarly, the efficacy of trading is called into question when there are no clear goals set for water quality. Perhaps the most important prerequisite for successful trading is a set of active participants, from champions within the permitting agencies to program administrators (middlemen) to the sources themselves (EPA 2008). While the administration of these trading systems is necessarily local, greater consistency is needed in program implementation to increase ease of use, participation and overall outcomes.

4.3.4 Soil Pollution Mitigation

Soil is a very important supporting unit of the ecosystem, and its degradation via human activities is increasingly catching public attention. The World Health Organization (WHO) lists ten chemicals with significantly high public concern; seven of them are related to soil pollution (Science Communication, 2013). These contaminants include heavy metals (e.g., lead and arsenic), pesticides (e.g., dioxin) and petroleum hydrocarbons, which are often created by the chemical manufacturing industry (EPA, 2012a). Arsenic, for example, is one byproduct in the pharmaceutical and glass industries, and mercury is used in various solvents (Science Communication, 2013). Plants directly take up contaminants through roots, which then indirectly affect animals and humans when they consume the plants (EPA, 2011a). For instance, mercury in soils can result in mental development declines of young children through direct ingestion of polluted soil and foods (Science Communication, 2013).

Natural ecosystems can remove pollutants from the soil, but the effectiveness of this removal service depends greatly on the surrounding environmental conditions (Donlon, 2006). Bioremediation as an ecosystem service-based approach degrades pollutants using plants provided with additional nutrients to accelerate their activity (Donlon, 2006). Microbes in the soil can absorb crude oil-derived contaminants (e.g., aromatic hydrocarbons, ester), and through their metabolism transform these contaminants into water and harmless gases (e.g., carbon dioxide) (USGS, 1997). The growth of microbes and depletion of hydrocarbon pollutants is enabled and accelerated by optimal soil conditions, including soil moisture, temperature, pH and nutrients (EPA, 2012a). Although the timeframe for bioremediation varies, it generally takes 130-184 days for oil hydrocarbons to degrade in soil (Viraraghavan et al., 1997). Bioremediation is largely used to remediate petroleum hydrocarbons, because they can be consumed as energy and carbon sources. Further studies are needed of the value of bioremediation to treat other contaminants, especially heavy metals (USGS, 1997).

Another ecosystem service-related approach is phytoremediation, which uses plants' root systems to transfer pollutants from deep soils to surface soils (Meagher, 2000). Meagher (2000) showed that with the help of genetic improvement technology, plants have greater ability to absorb some heavy metals and radionuclides. Accumulating the pollutants in the surface soil, and even the plant tissues, allows them to be easily removed from the soil system. For example, certain species of fungi combined with plants can increase the absorption rate of lead (Khakbaz et al., 2012) by penetrating into the plant root cells (Khakbaz et al., 2012).

Traditional soil pollution treatment often involves excavation, which requires large equipment and intensive labor (Ohimain, 2004). In the process, contaminated soil is often extracted and transported to a landfill designed to store contaminated soil (Ohimain, 2004). By comparison, bioremediation is relatively cost effective, particularly with large areas, because it does not require the continuous use of labor and equipment (EPA, 2012a). In addition, phytoremediation requires less space than excavation to restore polluted areas. Research shows that excavating or dredging 10-acre areas to a depth of 1 foot requires moving up to 20,000 tons of soil, while only 500 tons of biomass are needed to treat the same amount of polluted area

(USDA, 2000). Nonetheless, ecosystem service-based approaches seem to be effective only on specific pollutants. The bioremediation approach used to clean hydrocarbons might not be effective for removing heavy metals. Combining multiple approaches might be effective to treat various types of pollutants, but it will decrease cost effectiveness.

Businesses in the forest product industry have the potential to greatly influence the net quality of the soils through vegetation cover. The vegetation cover in forests, primarily trees, benefits the soil in multiple ways, including soil stabilization, erosion reduction, and sedimentation control (Krieger, 2001). By reducing soil and nutrient loss, forests protect and preserve soil productivity. Moreover, forests conserve and enhance the capability of soils to sustain diverse ecosystems. The trees themselves can reduce the volume of rain that reaches the ground through the interception of rain at the canopy level, which influences the soil-water system and increases the time it take water to cycle through the ecosystem. This process changes the activity of soil microbiota and contributes to the overall the productivity of the ecosystem (Forest Insights, 2005).

Few examples or case studies from either industry have documented the services of soil ecosystems. Nonetheless, much attention has been given to soil remediation for contaminants generated from byproducts of treating water and bioenergy. Efforts have been made in the Great Lakes region to increase soil retention by managing forest road building and harvests, simultaneously benefiting water quality (Weider & Todd, 2011). Scientists have also attempted to add biochar, a charcoal-like product created by burning woodproducts under low oxygen conditions, into forest soil to improve the soil's carbon-absorption abilities, thus mitigating the effects of climate change. Increasing the potential of soils to sequester carbon also benefits soil stabilization and at the same time the soil nutrient cycle (McElligott et al., 2011). However, some scientific trials have shown that the technologies used for soil remediation are uncertain and cost-prohibitive (Moore et al., 2011). Moreover, because the mechanisms of soil ecosystems are complicated and not fully understood, disturbing the complex subsurface community can have longterm effects that are hard to estimate (McElligott et al., 2011). As such, ecosystem-based soil remediation techniques are also unlikely to generate revenues, given the current state of knowledge about their costs and impacts.

4.3.5 Cultural Services

The Millennium Ecosystem Assessment report identifies six categories of cultural services that ecosystems provide: heritage value, cultural identity, spiritual services, inspiration sources, aesthetic value, and recreation and tourism (MEA, 2005). Despite the recognition of such services, their importance is not widely considered in landscape planning and management (Teneberg et al., 2012). Historically, cultural ecosystem services have been difficult to quantify due to the lack of data and methods available to analyze them (Pereira et al., 2005). A review conducted by Daniel et al. (2012) indicates that valuing landscape aesthetics, cultural heritage, outdoor recreation, and spiritual significance can lead to opportunities for increased ecosystem management. These cultural values can be quantified with recent methodological developments within the social and behavioral sciences (Daniel et al., 2012). Knowledge of these cultural values does not necessarily mean that they can be effectively captured by the organizations investing in management of cultural ecosystem services, although expanded ecotourism has been seen as one way to support ecosystem management (Daniel et al., 2012; MEA, 2005).

While tourism and recreation in natural settings are increasingly acknowledged and valued as services provided by ecosystems, spiritual and inspirational attributes are more difficult to capture. These attributes are influenced by temporal factors, such as the sociopolitical climate, leaving them more prone to periodic deterioration (Pereira et al., 2005). The Millennium Ecosystem Assessment (2005) includes a number of regional evaluations of cultural services provided by intact ecosystems. Most of the studies considered tourism as a cultural service (e.g., Caribbean Sea, Laguna Lake Basin, Portugal, Downstream Mekong, SAfMA Regional, and Sao Paulo) and few assessed spiritual, aesthetic, recreational and educational services. Tourism services have received greater focus because they are much easier to quantify than spiritual and inspirational benefits. Techniques used to assess tourism value include economic valuation based on expenditures, visitor numbers, and the potential for ecotourism industry development (Daniel et al., 2012).

Despite the positive global trends in cultural ecosystem tourism values, there seems to be little opportunity for increased participation by private forest owners within the U.S. At present, timber products companies with large landholdings commonly create leases for hunting and other recreation on their lands, generating considerable income. However, expanding such opportunities to the general public would not only require a substantial investment in tourism infrastructure, but also comes with liability risks and increased risk of forest fire. Additionally, the U.S. already provides ample opportunities for low-cost ecotourism in federal and state forests and parks, so the opportunities to derive income from private forest tourism ventures may not justify the cost of supplying it outside of specialized interests, such as hunting clubs, which many timber products firms already accommodate.

4.3.6 Noise Reduction through Vegetative Buffers

Manufacturing of chemicals and forest products often causes noise pollution from large machines such as saws, compressors, and vacuum pumps (NIBUSINESSINFO, 2013), degrading living conditions in the surrounding areas (Georgia Forestry Commission, 2008). A number of studies have shown that planting tree buffers reduces noise escaping from manufacturing sites (Georgia Forestry Commission, 2008; USDA, 2008). Screening with natural vegetation is recognized by the U.S. Federal Highway Administration, (FHWA, 2011) as a very important way to reduce noise pollution, so creating vegetation buffers around manufacturing sites is likely to be similarly effective. Although solid barriers such as concrete walls and buildings are more efficient for reducing noise pollution, natural vegetation not only has the potential to reduce noise, but also has the additional advantage of providing aesthetic value and improved water and air quality (Beal, n.d.). Tree buffers create natural habitat for other organisms (Georgia Forestry Commission, 2008). Evergreen trees are superior to deciduous trees for reducing noise because they provide a leafy, noise absorbing buffer year round (Georgia Forestry Commission 2008). Costs of mitigating noise through planted buffers include not only planting costs, but also the ongoing maintenance costs associated with trimming and cleaning leaf litter. The reduced noise benefits the whole community by increasing property values in the area (Nelson, 2007). In addition, a manufacturing facility surrounded by a tree buffer is an appropriate symbol that creates an image of an environmentally friendly company.

4.3.7 Coastal Wetlands as Hurricane Mitigation/Resilience

Coastal flooding is projected to become more frequent due to extreme weather events triggered by climate change (Arkema et al., 2013; IPCC, 2013; Dow Chemical Company and

The Nature Conservancy, 2012). For businesses operating in coastal areas, flooding may cause significant disturbances. Events such as hurricanes cause various types of damage, including physical damage to buildings from tidal flooding and winds and disruption of utility and transportation networks (Wasileski et al., 2011). Business operations, especially manufacturing processes, are vulnerable to infrastructure damage, which can cause tremendous economic loss or even prompt businesses to relocate (Tierney, 2006). Chemical manufacturing sites are often located on rivers or near coastlines due to their high water usage and discharge, and thus are easily affected by hurricanes (Schiller, 2011; Harris & Wilson, 2008). Aside from possible economic losses, extreme weather events also increase the chance of chemical contamination of the surroundings. The National Academy of Engineering (2006) states that flooded chemical factories have become sources of toxic pollutants to nearby streams and that toxic materials might stay in soil and sediments long after the flood recedes (The National Academy of Engineering, 2006). Mitigation of hurricane damage is thus very important to chemical manufacturing businesses for both economic and environmental reasons.

Recent studies have highlighted the importance of healthy coastal habitats for reducing damage from extreme environmental events such as hurricanes (Arkema et al., 2013; Jones et al., 2012). Marshes, coastal forests and seagrass beds function as buffers from waves and provide erosion reduction (Arkema et al., 2013). Depending on the local circumstances, an ecosystem-based risk mitigation approach may be less costly than conventional man-made infrastructure approaches (Jones et al., 2012). For example, the costs of marshland stabilization and restoration in New Orleans are estimated to be \$2 and \$4 per square meter, respectively. These costs are much lower than the cost to strengthen the existing concrete floodwalls, \$8000 per meter (Jonkman et al., 2013). Moreover, conserved coastal habitats provide other benefits, including food security, sustainable water management, and recreational opportunities (Jones et al., 2012). However, given the long-term nature of risk reduction from habitat conservation, the exact magnitude of avoided damages from coastal habitat conservation is difficult to measure accurately. Due to the long-term, unpredictable protection benefits, coastal habitat might not be suited for protecting facilities from immediate damage. In contrast, it is clearer how to measure the protection provided by manmade structures, making it relatively easy to create a construction plan to avoid catastrophic damages to manufacturing facilities (Arkema et al., 2013). Nonetheless, the ecosystem-based approach has a high potential because it provides low-cost, long-term risk mitigation that could not be achieved using manmade structure requiring continuous maintenance (Jones et al., 2012; Arkema et al., 2013). As a result of these differences, businesses could obtain new benefits from coastal habitat conservation.

4.3.8 Habitat and Biodiversity Protection through Ecosystem Management

Habitat and biodiversity protection present a challenging opportunity for the forest products industry. Biodiversity has a number of scientific measures, but on its simplest level it relates to the number of species within an area and is intrinsically tied to the habitat and ecosystem health (Simberloff, 1999). As the most diverse ecosystems on land, forests harbor many unique species, some of which have yet to be discovered. Forests provide habitat, food, water, and countless other commodities and services for wildlife (CIFOR, n.d.). Forestland management and timber extraction can have an outsized influence on habitat health, to the detriment of biodiversity. However, the increasing awareness of scientists, governments, and forest landholders of the adverse effect on biodiversity of harvesting, deforestation and forest management has led to active research and participation in systems to reduce forestry's destructive impacts. Activities to reduce these impacts include ecosystem management, mitigation banking, and development of protected areas (Simberloff, 1999; Forest Trends, 2011).

Ecosystem management, a management paradigm whereby the ecosystem is managed by focusing on its structure and processes, has gained popularity in forest management. For example, retaining multiple age classes on the land as opposed to creating a uniform forest through clear-cutting has the ability to create a forest more structurally similar to undisturbed forests. However, there is no scientific consensus that such management is optimal from a biodiversity standpoint (Simberloff, 1999). Others favor a more conservation-oriented approach, whereby lands are set aside for conservation purposes, including biodiversity protection. In fact, some large-scale forestry firms have conveyed valuable conservation land to land conservation trusts (e.g., Wagner Forest, 2013). This is done for a number of reasons; commonly, they are lands that are of low value for timber but high value for conservation, or they are too small and remote to be profitably managed. In return, the forest landholders receive cash, tax breaks, or even other land (Stein, 2011).

Finally, there is the possibility for forestland owners to participate in compensatory conservation or mitigation programs, where payments or market mechanisms are used to incentivize conservation. Conservation and mitigation banks are programs in which landowners are paid to offset potentially detrimental impacts on species or habitats due to development elsewhere. Buyers in the bank are typically developers who must offset their development impacts as a permitting condition (Forest Trends, 2011). In the U.S., these programs have focused on wetlands, but there is a growing movement to include other habitat types, such as forests (USFWS, 2013). However, the number of programs is limited, and, like water quality trading, the legal, regulatory, and even scientific frameworks are tenuous (Simberloff, 1999; Forest Trends, 2011).

4.3.9 Forest Biomass Fuel Provision

Highly productive planted forests currently provide a large and growing share of the wood required by the forest products industry, and policy-driven demand for forest biomass in energy production is increasing (WBCSD, 2012). There is a nascent export market for wood pellets in the U.S., driven by the E.U.'s renewable energy policies (Qian, 2013). Given this growing demand, forest owners and forest product companies should investigate diverting residual harvest materials to fuel pellet producers, who make wood fuels for boilers and power plants.

A number of parties can benefit from the forest biomass market, including suppliers, consumers and environmental interests. To the forest products industry, biomass markets provide a new use for low value wood residuals—byproducts from forest harvests, lumber milling, and paper production. To consumers facing regulatory requirements for renewable sourcing, wood biomass is economically competitive with other renewable options for electricity generation (Index Energy Services, 2014). And, if sourced from properly managed forests, wood pellets can be a sustainable, carbon neutral energy source (The Alliance for Green Heat, 2013).

In recent years, worries have surfaced that the removal of forest biomass residuals from forests will result in long-term risks for forest health, such as lower soil fertility and nutrient availability. Not only does the forest biomass industry divert materials from harvest sites that would otherwise be left to recycle nutrients, but it may also begin to increase competition for higher-value timber, driving up prices (Siceloff, 2013). The EU has attempted to respond to some of these issues by requiring wood pellets be sourced from sustainably managed forests, but compliance and enforcement may be difficult. However, strict compliance may drive up costs and drive suppliers out of the market (Berg & Lovaglio, 2012). The large effect that policy shifts can have on this market indicates that participants should be active in advocating for fair policies, while continuing to monitor long-term environmental effects (Lorber, 2013).

4.3.10 Corporate Image Improvement through Conservation of Ecosystems

Social responsibility, including ecosystem protection, is a key element of a company's corporate image. Research done by APCO Worldwide shows that social responsibility is one of the main aspects in determining the reputation of a business (Wolf & Dumont, 2010). In the chemical industry, environmental damages caused by chemical discharges and catastrophic accidents can damage not only their reputations, but also their market values (Harris, 2010). For example, the market value of Exxon dropped by billions of dollars after the Exxon Valdez oil spill in 1989 (Beder, 2002). Accordingly, ecosystem investments can play an important part in demonstrating social responsibility within the forest products and chemical manufacturing industries.

There are various reputational benefits for companies in both industries to gain by investing in ecosystem services. First, they can help companies establish an environmentally sensitive corporate image. For example, Responsible Care is a global initiative aimed to help chemical companies incorporate environment and sustainability issues throughout the manufacturing process to show their leadership in the environmental issues. By joining the organization, companies demonstrate a commitment to environmental protection (ICCA, 2009). Currently, 53 chemical companies are members, trying to show their social responsibility to the public (ICCA, 2009). Also, a positive environmental reputation helps a chemical company differentiate itself from competitors. Research shows that reputation is critical when consumers have little information to assess a product's performance, which is particularly difficult for chemicals (Beder, 2002). Customers usually cannot tell the quality of a polymer or a pesticide from the appearance of consumer products, thus the reputation of the company significantly influences customer decisions (Tuominen, 1999). Currently, chemical companies often gain reputation by cooperating with environmental organizations or providing funds for ecosystem-related projects (Beder, 2002). One obstacle for obtaining a positive reputation is the difficulty of assessing reputation in general. There are, however, a few indicators that track this, such as the

Dow Jones Sustainability Index. This index tracks widely-recognized companies, publicly evaluating their environmental sustainability performance (Dow Jones, 2014).

4.4 Discussion of Identified Opportunities within the Industries

When examining the opportunities identified for the chemical manufacturing industry and the forest products industry, there appear to be at least three ways in which ecosystem services can provide value to a company. They can provide an innovative means of meeting regulatory standards, they can supplement or supersede a traditional infrastructure solution, or they can take the form of new products and services for the company to market. The three at times overlap, and are not mutually exclusive; for example, the use of constructed wetlands to treat wastes is an innovative strategy to meet regulations, and it supplements traditional infrastructure techniques. On balance, however, there is a trend that emerges when contrasting the matrix of opportunities developed for the chemical manufacturing industry with that developed for the forest products industry. The former are largely composed of projects that are driven by innovative solutions to regulatory concerns or environmental hazards, while the latter are mostly demand-driven opportunities to enter nascent ecosystem markets, with potentially little effect on the traditional forest business (Stein, 2011; Siceloff, 2013).

This difference between the two sectors points to a fact that seems to underlie what makes an ecosystem service opportunity more successful in the near-term—the ability to market new products and services. Given that most of the forest product industry's opportunities allow that, we would expect to see greater interest in ecosystem services from this sector. For example, a number of forestry firms have begun seeking opportunities within the forest carbon markets and forest biofuels provisioning markets, both of which can help sustain local forest ecosystems while providing global climate maintenance (Finite Carbon, 2013; Nielson, 2011; Siceloff, 2013). We also may be able to extrapolate trends from the two industries considered to other similar industries. For example, one could expect agriculturally intensive industries to have opportunities to engage in ecosystem markets similar to those of the forest products industry, given the land-intensive nature of each business. On the other hand, the opportunities available to oil and gas or even heavy manufacturing industries may be more analogous to those in the chemical manufacturing industry, given the localized nature of their impacts. Overall, however, while the number of opportunities may be greater in the forest product and other land-intensive industries, the level of participation remains marginal (Forest Trends, 2012).

Aside from the occasional opportunities provided by innovative markets for ecosystem services and sustainability-oriented product lines, there has not been wide interest from either the forest products or the chemical manufacturing industries in significantly investing in ecosystem services or in using ecosystem service solutions to treat wastes and maintain a healthier environment—the "green infrastructure" solution. Our research suggests two aspects to this failure to invest in the development of ecosystem services and green infrastructure. For the most part companies do not explicitly recognize these failures, but the failures are reflected in the types of projects that have gained traction among participants and the financial disclosures companies make with regard to environmental risk.

The first failure is a result of economic and policy failings leading to a lack of readily available programs to monetize the societal benefits that corporate ecosystem service investment and valuation provide. Companies are only going to invest in ecosystem services and green infrastructure to the extent that they perceive a return from that investment, or to the extent they are required or incentivized to do so by direct government regulation. This observation is supported by a 2002 review of forest ecosystem service investment conducted by the International Institution for Environment and Development (Landell-Mills & Porras, 2002). The study indicates that the two most important drivers of forest ecosystem service investment are demand-side forces and government regulation. For the most part, the successful opportunities we found with our analysis are areas where government regulation has driven demand for an ecosystem service or product, such as the California Carbon market driving forest carbon provision and the EU's climate directives driving development of wood biomass markets (Siceloff, 2013; Finite Carbon, 2013). No analogues were identifiable for the chemical manufacturing industry; perhaps this is an indication that returns from ecosystem investment in the chemical sector are too low to drive the widescale ecosystem management needed to promote real change. However, freshwater provisioning and regulating services seem ideal for more widespread participation, given widespread demands, close regulatory scrutiny in many jurisdictions, and the risks posed by inadequate protection of water supplies.

The reality of low return from ecosystem investment is closely related to the second aspect of failure, which is that companies currently perceive their exposure to ecosystem risk as limited and manageable. For the most part, the negative consequences of ecosystem stress, for example water availability, are largely ignored or minimized in official corporate shareholder reports unless deemed material under securities law. Using the chemical industry as an example, while both DuPont and Dow Chemical make note of efforts to reduce water use within their sustainability literature, their official annual reports do not point out risks related to water availability separately from other raw materials risks, although they do note compliance costs due to remediation of water contamination. Only material litigation risks due to failure of environmental safeguards or non-compliance with environmental regulations are explicitly detailed (Dow, 2013b; Du Pont 2014).

Forest products firms have largely followed the same pattern. Aside from sustainably managing their timber resources over the long term, forest product companies have not been good at self-regulating (Ellefson et al., 2004). Where societal risks are perceived as large—such as soil compaction and water sedimentation problems associated with forest harvest—governments have needed to step in to require or promote changes to forestry activities, such as development of best management practices (BMP) to prevent erosion and stream siltation resulting from harvest activities (Ellefson et al., 2004). The shareholder reports of forest products companies tend to focus on environmental risk to the extent that it affects their bottom line. For instance, the shareholder reports of the Potlatch Corporation list fire and other hazards to standing timber as financial uncertainties, as well as changes in "extensive environmental laws and regulations," but do not call out any ecosystem risks, simply stating that unstated risks are deemed immaterial (Potlatch, 2012). Essentially the same language appears in the Weyerhaeuser shareholder report. Only the latter mentions the word ecosystem, and only once at that (Weyerhaeuser, 2013c). Until the level of ecosystem-specific risk rises to the level where companies perceive a significant risk to their operations, or policies evolve to the point where companies can recoup material financial returns from ecosystem investment, we hypothesize that activity from the chemical manufacturing and forest product sectors will remain limited.

One thing to note is that many companies in both the chemical and forest products sectors mention environmental risks in their financial reports or their sustainability reports, indicating that companies realize that failure to track environmental concerns can have negative economic consequences (Dow, 2012; Weyerhaeuser, 2012). This is a step in the right direction, and it is increasingly common in corporate disclosures for industries ranging from semiconductor manufacture to apparel manufacturers. However, these disclosures are typically boilerplate, lacking details on specific risks, or worse, quickly pivoting to discuss how their products help alleviate their customers' risks (Dow, 2013b; Du Pont 2014). Companies should work to track and disclose material ecosystem risks publicly (Ceres, 2010).

Assuming, however, that companies are indeed interested in taking steps to both mitigate their ecosystem risks and benefit from ecosystem service projects, they must have a methodology to determine which of the opportunities that they have identified as relevant to them should be prioritized for development. In Section 5, we discuss a methodology for businesses to do just that. We develop a systematic approach for assessing a project's potential value to the company using a set of criteria important to businesses.

5 Assessing Ecosystem Values from the Business Perspective

Business managers need a tool to prioritize the range of ecosystem service opportunities identified as relevant to their business. We feel that a scoring framework will be vital to allowing them to classify the benefits that various ecosystem service projects can provide them. To that end, we have designed a system that uses multi-criteria analysis (MCA) to rank the attributes of potential ecosystem service projects based on criteria most important to the company. MCA is often used in planning processes when there are a number of stakeholders with competing interests or competing projects to be evaluated, such as land use planning. It allows managers to compare projects when the criteria involved are not measured in common units. As the UK government's manual on MCA explains, MCA enables users to take the options available, and, by exercising judgment, classify them based on a set of explicit, pre-defined criteria (DCLG, 2009).

The literature on MCA indicates that it has several uses, which range from helping users distinguish the differences between options to helping people actually choose the best option based on their needs (DCLG, 2009). Based on discussions with our client and business values identified in the ecosystem valuation literature (e.g., TEEB, WBCSD), we have chosen to score the projects using a weighted sum of the following five criteria: financial value to the firm (F), reputational benefits (R), environmental hazard/risk reduction (E), policy and regulatory regulating conditions (P), and the level of knowledge and activity in the field (K). These major criteria are, in turn, comprised of the weighted sums of several sub-criteria. By combining weighted sub-criteria scores, we get a sense of how each project performs with regard to each major criterion. The major criteria are then weighted and combined to achieve an overall project score, the weighted composite score. Weights reflect the users' best guess of each criterion's overall importance to the project's value. Project scores are relative and dependent on the suite of projects compared at one time.

The weighted composite score for each project is defined as follows (w_x represents each criterion's weight):

$$S = w_f F + w_r R + w_e E + w_p P + w_k K$$

When it comes to evaluating a project against these criteria, the process should be objective, but there may be some subjectivity when it comes to creating weighted scores and determining each attribute's relative importance (DCLG, 2009; Hammond, Keeley & Raiffa, 1999). In this sense, converting the results from a series of attributes to a ranked list requires the use of value judgments in establishing weights of the criteria, given the needs of the company and estimates of specific values. In our example evaluations below, we have included hypothetical values based on a number of assumptions tied to a set of hypothetical projects. Managers implementing this technique would use values specific to their cases. However, we believe that by undertaking this analytical process with even a basic level of data, managers will gain a better understanding of how projects compare, and whether their company stands to benefit by pursuing various ecosystem service opportunities.

5.1 Hypothetical Projects Examined:

In order to both explain the assessment criteria and demonstrate the application of our scoring framework, we examined three hypothetical projects, elaborating on the generic opportunity descriptions listed in Section 4. For the sake of incorporating projects from both the forest products industry and the chemical manufacturing industry, we assume that the opportunities are to be evaluated from the point of view of a diversified company with both a forest products and chemical manufacturing arm seeking to determine their greatest opportunity for ecosystem service investment. Using the system of identification we presented in Section 4, we have decided to focus on three projects for further investigation and scoring.

1. <u>Constructed wetlands for pulp and paper mill wastewater management</u>. This hypothetical project is located near the Texarkana mill in the City of Texarkana, in Northeast Texas (International Paper, 2014). According to the Interstate Technology & Regulatory Council (2003), the typical water pollutants from pulp and paper mills are measured by biochemical oxygen demand (BOD) and total suspended solids (TSS). Increased BOD is often caused by excess organic matter (wood particles, fiber particles) created in the

paper production process (ITRC, 2003). TSS can include various types of solid pollutants, but we assume that it does not contain any toxic chemicals or heavy metals. The scale of this project is 10 acres, with a proposed cost of $1 million. (Values adapted from ITRC, 2003).

2. Coastal habitat protection for hurricane risk mitigation. The example coastal wetland investment project used in this analysis is the pilot site developed by The Dow Chemical Company to protect its Freeport, Texas chemical manufacturing facility from hurricane damage. Located only 12 km inland, Dow's Freeport facility is vulnerable to hurricanes because of its proximity to the Gulf of Mexico, its low elevation at approximately 3.8 meters, and location of major components of the production facility outside of the primary levee that protects the town of Freeport. While Dow intends to construct levees to protect its facility, it also considered using the extensive marshes that surround the property, which are partially protected in the Brazoria and San Bernard National Wildlife Refuges. Dow Chemical used these areas to study the potential of restoring 10 km^2 of marshland and incorporating 5 km^2 of existing marshes into its hurricane risk mitigation strategy.

3. Carbon sequestration through improved forest management and reforestation. The project we are reviewing is a hypothetical project in the East Texas Piney Woods region just north of the Gulf Coast. To create an appropriate description for this project, we have looked to the Climate Action Reserve's (CAR) project database (CAR, 2014), which, as of March, 2014, provides a list of and documentation for 29 forest carbon offset projects that have been issued credits under their system. To receive credits for improved forest management, the most common project type, project developers must show that their land has higher carbon stocks than is the common practice in their area, and they have achieved this by either reducing harvest levels, increasing harvest-rotation length, or a mixture of the two practices (CAR, 2012). We assume the project would be equivalent to the median size and productivity of projects in the CAR system. From an analysis of 28 registered CAR projects, the median size would be a four thousand acre project (range of

106 acres to 103,000 acres) producing 50 carbon credits per acre/decade (range of 1.3 offsets per acre to 205.5 offsets per acre) for a total of 200,000 carbon offset credits (CAR, 2014).

5.2 Financial Value (F)

This assessment criterion is intended to judge any financial benefits or losses that will accrue to an organization undertaking a particular project. How a project's activities affect costs and revenues is extremely important, so a ranking system must take these concerns into account (TEEB, 2012). A project's financial value score is an intermediary score based on its expected revenue generation and cost impacts. Note that costs and revenues are handled separately, not netted.

1. Revenue impacts represent the estimated revenue that a project could be expected to generate in present value terms. If there is a range of expected values, we recommend using the low-end value for conservativeness. Another approach is to calculate the financial values for both endpoints of the range to determine its effect on project scoring.

2. Cost impacts represent the present value of expected costs to conduct the project. If a project is expected to reduce costs overall, then the net value of reduced costs is classified as a "cost reduction." If, on the other hand, a project is expected to add to net costs, the costs are classified as "added costs."

As an example application, we estimate that the hypothetical constructed wetland for the treatment of pulp and paper mill wastewater can generate \$0 to \$1.4 million of revenue through the sale of wetland mitigation banking credits or other habitat credits, based on what has been achieved by similarly sized projects tracked by the Interstate Technology and Regulatory Council (ITRC, 2003). This assumes a 7% private discount rate, which is the rate used in several analyses conducted under the TNC-Dow collaboration. Given the uncertainty of revenues, we conservatively assume \$0 in potential revenues from this project.

We base the cost impacts on pulp and paper mill industry average regulatory compliance costs. According to an EPA study, the average regulatory compliance costs are slightly less than 10% of total per-unit manufacturing costs (EPA, 1977). We assume 50% of the regulatory compliance costs are for effluent control, and a project can reduce this cost by 5% net of any costs for developing the treatment wetland. We used an economic analysis of U.S. paper industry production costs (McCarthy & Urmanbetova, 2008) and estimated the value of such a project at an average-sized plant to be $2,700,000 in present value terms. These raw sub-criterion results are summarized in Table 4. Weighted scoring will be demonstrated after the other criteria have been introduced and raw values determined for the other projects under consideration.

Table 4: Expected financial value of the constructed wetland project.

	Financial Value		
	Revenues	**Cost Reduction**	**Added Costs**
Project 1 - Constructed Wetland	$0	$2,700,000	$0

This simplified, heuristic approach to determining business value allows for a quick, high-level comparison of the competing projects. However, it should be noted that social values—monetary and non-monetary benefits that accrue to the larger community—are not taken into account in this analysis; we feel that incorporation of these values does not accurately reflect the financial considerations of business decision makers. To the extent that social values are present in our analysis, they are reflected within the next criterion, reputational benefits.

5.3 Reputational Benefits (R)

We used this assessment criterion to classify the reputational benefits that a company may gain from undertaking a project. In this context, reputational benefits are defined by how the project is related to public environmental interests: the more highly the project relates to public environmental interests, the more potential there is for reputational benefits. We use a proxy measure to capture these potential reputational benefits— the public's concern for various environmental issues, as established by an annual Gallup Poll (Gallup, 2013). The poll assesses public concern with regard to pollution of water bodies (e.g., rivers, lakes and reservoirs), air pollution, the loss of tropical rain forests, soil contamination, pollution of drinking water, extinction of plant and animal species, loss of open spaces, climate change, water scarcity, damage of the ozone layer, acid rain, the loss of natural habitat, and ocean pollution. We have condensed these issues into six categories of interest: water, air, soil, forest, climate change, and biodiversity. The reputational benefits score is based on the number of public interest topics related to the project, and the intensity of public interest, as described below.

1. "Number of public interests topics related to the project" is simply the number of the six identified public interests (water, air, soil, habitat, climate change and biodiversity) the project relates to. All stages of the project (planning, construction, and operation) and both direct and indirect effects of the project should be considered when making this determination. These results are meant to demonstrate the variety of public interest concerned with the project or activity. The more interests that are involved, the higher the potential reputational gains from undertaking the project.

2. The "intensity of public interest" is based on what percent of the national Gallup Poll respondents indicated "most concern" for each of the six interest categories in 2013 (Table 5). Each public interest identified as related to the project in the first step is included in the assessment. We averaged the percentages of the related interests to determine the intensity of public interest raw score. We assume that a project related to environmental issues that the public is more concerned about provides a greater potential reputational benefit.

Table 5: The percentage of respondents indicating "most concern" for six environmental interest categories (Gallup, 2013).

Water	Air	Soil	Habitat	Climate Change	Biodiversity
49%	32%	45%	36%	36%	35%

As an example application, we assume that the hypothetical constructed wetland for the treatment of pulp and paper mill wastewater is related to water, soil, and habitat public interests; hence, the number of public interest topics related to the project is three. The percentage of the public indicating "most concern" for these interests is 49%, 45%, and 36%, respectively. This results in an intensity of public interest score of 43.3. These raw sub-criterion scores for reputational benefits are summarized in Table 6.

Table 6: Reputational benefits from the constructed wetland project.

	Reputational Benefits	
	Variety of Public Interests	Average Percent of Public Indicating "Most Concern" in Gallup Poll (%)
Project 1 - Constructed Wetland	3	43.3

5.4 Environmental Hazard/Risk Reduction (E)

The environmental risk reduction category develops a score to judge the potential of a project to reduce a company's exposure to environmental risks. The level of environmental risk exposure is described as the probability of an environmental disaster of a specific size occurring. Environmental risk is described as the probability of an event occurring times the consequence of experiencing the particular environmental hazard. This definition allows users to incorporate the broad idea of environmental risk as a hazard or danger with adverse probabilistic consequences. In the framework, users first examine the potential of reducing environmental risk from engaging in a new activity, such as mitigating storm swell exposure through coastal wetland restoration.

There are three categories of evaluation applied to each project: identification of potential risks ("risk reduction potential"), classification of risk, and comparison to traditional, or "gray," infrastructure.

1. Risk reduction potential refers to whether a project being evaluated has the potential to reduce exposure to identified environmental hazards. If there is no potential for the project to reduce such an exposure, then the project receives a risk reduction potential of "none." If there is an unknown potential for the project to reduce risks, then the result is "unknown." If there is a known potential for the project to reduce risks, then the result is "known." These descriptive terms have associated raw scores of 0, 1, and 2 respectively.

2. Next, we characterize the type of risk the project may help to reduce as "direct," "indirect," or "direct and indirect," or "N/A." These correspond to raw scores of 1, 2, 3,

or 0, respectively. Direct risks are defined as hazards that can potentially damage a company's physical assets. Indirect risks are defined as hazards that can negatively affect company processes and activities, such as limiting availability of raw materials or access to markets. Projects receive a "N/A" score if the possibility of risk reduction is described as "none" in Step 1.

3. Finally, we consider the effectiveness of the solution for reducing environmental risk compared to traditional infrastructure. Users compare the potential mitigation benefits afforded by the new activity or project to the levels of protection provided by traditional alternatives, such as engineering solutions. This comparison should be based on the practical comparability of the ecosystem solution to the traditional infrastructure used to mitigate the risk. The comparison can be "more effective," "equally effective," or "less effective," or "unknown" if the either the risk and/or its effectiveness as compared to the traditional infrastructure is unknown. These outcome determinations correspond to raw scores of 3, 2, 1, or 0 respectively. Unknown receives the lowest score because we cannot accurately gauge a project's risk reduction effectiveness without identifying and understanding the mechanism by which it reduces risk.

While this framework does not quantify the magnitude of risk, its simplicity allows businesses to rapidly consider potential activities and evaluate their potential benefits. As an example application, we assume that the hypothetical constructed wetland for the treatment of pulp and paper mill wastewater has an "unknown" potential to reduce risk of exposure to environmental hazards. Since the constructed wetland is only 10 acres in size, it is unlikely to provide significant risk mitigation from flooding or provide resiliency against other hazards. Given that the risk reduction potential is "unknown', the type of risk receives a "N/A" characterization. Finally, constructed wetlands are assumed to be "less effective" than traditional wastewater plants for managing wastewater concerns. These raw sub-criterion scores for environmental hazard/risk reduction are summarized in Table 7.

Table 7: Environmental hazard/risk reduction potential for the constructed wetlands project.

	Environmental Hazard/Risk Reduction		
	Risk Identification	Risk Characterization	Comparison to Traditional Infrastructure
Project 1 - Constructed Wetlands	Uncertain (1)	N/A (0)	Less effective (1)

5.5 Policy and Regulatory Enabling Conditions (P)

This section analyzes the policy and regulatory enabling conditions for ecosystem service-related activities. Ecosystem valuation is a complicated procedure that is greatly influenced by environmental policy conditions (TEEB, 2012). The policy sphere can directly impact the value of an ecosystem service, and policies can also provide the means to effectively realize that value. Therefore, the government's attitude, represented by the quantity and influence of relevant policies, is a crucial aspect of project feasibility. This section scores the policy-enabling conditions for ecosystem-related activities based on the existence of related policies or regulations, the scale of the policies and regulations, and the influence of the policies and regulations. These are determined as follows:

1. The existence of related policies or regulations is fundamental to the policy and regulatory scoring criterion. Are there known national, state, county, or local policies or regulations related to this project? If so, determine how many. We use the Federal Register[1] to explore policies or regulations that may relate to the projects, developing the following protocol:

    - List up to 5 key words associated with the potential project that could be used to find policies or regulations related to the project. For example, a project using a constructed wetland for wastewater treatment may use key words such as "clean water," "wetland," and "waste."

[1] "The Federal Register is updated daily by 6 a.m. and is published Monday through Friday, except Federal holidays, and consists of four types of entries: 1) Presidential Documents, including Executive orders and proclamations, 2) Rules and Regulations, including policy statements and interpretations of rules, 3) Proposed Rules, including petitions for rulemaking and other advance proposals, 4) Notices, including scheduled hearings and meetings open to the public, grant applications, administrative orders, and other announcements of government actions." www.federalregiser.gov

- Go to https://www.federalregister.gov/articles/search. Enter all of the key words in the search box to search for articles in the Federal Register, and search all dates in the archive.

- Use the article counts on the left hand side of the search page that summarize the results by type of article (proposed rule, rule, notice, presidential document) or topic (e.g., environmental protection, waste treatment and disposal, water pollution control, etc.). Choose "rule" and "proposed rule," then count the number of articles within the top 50 returned that are relevant. It is important to use this approach across all projects and to count only articles found using the same categories (e.g., all articles relating to the search terms or only to articles relating to both the search terms and to "rules").

2. We determine whether the scale of the policy's effect is national or subnational. We assume that national policies present a greater opportunity to scale up projects in a large number of sites, resulting in a stronger enabling condition. In this case, we count the number of policies discovered in Step 1 considered to have a national effect. While the Federal Register tracks national policy, many of the rulemakings pertain to specific jurisdictions, such as states or federal agency districts or regions.

3. We base the influence of the policy on whether the policies regulate the central project activity or purpose. The influence of the policy is characterized by whether it is centrally or peripherally related to the project. We assume that policies that are centrally related to the project would have greater influence than those that are only peripherally related to the project. If there is policy that influences or regulates the central activity of the project, it receives a "yes" on this sub-criterion. Otherwise, if policy only affect some peripheral activities related to the project, the result is "no." These correspond to raw scores of 1 and 0, respectively (Table 8).

Table 8: Potential policy and regulatory enabling conditions for the constructed wetlands project.

	Policy/Regulatory Enabling Conditions		
	Number of Policies	**Number of National Policies**	**Do Direct National Policies Exist?**
Project 1 - Constructed	20	2	Yes (1)

Wetland

5.6 Level of Knowledge and Activity in the Field (K)

This assessment criterion measures the status of any scientific, economic, or technical knowledge necessary to undertake the ecosystem service projects. This section will estimate the level of subject matter knowledge and expertise in the areas related to the project. This criterion is important to assessing the feasibility of the project, as well as the additional costs or time related to knowledge or the development of practical tools. Essentially, it is a proxy measure for establishing a project's scientific and technical feasibility. There are four sub-criteria for consideration: the depth of academic literature, the availability of data or tools, the existence of previous projects, and the existence of organizations as potential project partners.

1. We determine the depth of academic literature by following these steps:
    - List up to 5 key words associated with the potential project that could be used to search academic literature related to the project topic.
    - Use an academic web search tool such as Web of Science (http://workinfo.com) or Google Scholar (http://scholar.google.com/) to determine the number of academic articles related to the project. We used Web of Science, searching all dates in the archive.
    - Enter the key words in the in the search tool of choice.
    - Count the number of applicable articles in the first 50 articles.

2. We determine the availability of data or tools to assess project feasibility by following these steps:
    - Search for ecosystem-related data and tools to evaluate ecosystem services.
    - The results are either "present," reflecting the public availability of applicable tools or data, or "absent," indicating no publicly available tools or data. These correspond to scores of 1 or 0, respectively.

3. We determine the existence of previous or ongoing projects by following these steps:
    - Search for previous or ongoing projects in the field of interest within the articles found during previous steps or in reports from consulting firms, non-profits, industry associations, other companies, and governments.

- Count the number of ongoing projects. Users may want to limit the count to projects that are well documented with information on the project cost, procedures of the project and a timeline, and detailed results. This information may be important during the assessment of project feasibility.

4. Existence of environmental groups and consulting firms as potential partners is scored by following these steps:
   - Count the number of consulting firms, non-profit organizations, or academic groups that could be contracted for professional services or could be partnered with to accomplish the work. This information may be obtained from expert knowledge, web searches, publications, and/or documentation from other projects.

As an example application, we found that that there are six articles related to constructed wastewater treatment wetlands in the Web of Science. Secondly, our search for data and tools showed that the Natural Capital Project has a water purification model that estimates the contribution of vegetation and soil to water purification (The Natural Capital Project, 2012b). Our research indicated the existence of at least seven constructed wetland projects focusing on reducing biochemical oxygen demand and suspended solids, as listed in a report by the Interstate Technology & Regulatory Council (ITRC, 2003). Finally, we found at least four potential project partners or organizations, including the Interstate Technology & Regulatory Council, the US EPA, the Natural Capital Project, and The Nature Conservancy.

Table 9: Level of knowledge and activity in the field for the constructed wetlands project.

	Level of the Knowledge and Activity in the Field			
	Depth of Academic Literature	**Existence of Publicly Available Data/Tools**	**Number of Projects**	**Number of Organizations for Potential Project Partners**
Project 1 - Constructed Wetlands	6	Yes (1)	7	4

5.7 Applying the Criteria to the Remaining Projects

In this section, we demonstrate the application of our scoring system to the remaining two projects: the reduction of hurricane risk via coastal habitat conservation and carbon sequestration through improved forest management.

5.7.1 Project 2: Coastal Wetland Conservation to Mitigate Hurricane Risks

This project is based on Dow and TNC's investigation into the feasibility of replacing traditional seawalls with coastal habitat restoration projects near Dow's Freeport, Texas, facility. Dow considered restoring the extensive marshes that surround the property, which are partially protected in the Brazoria and San Bernard National Wildlife Refuges.

Financial Value (F)

1. Revenue impacts
   - The project provides opportunity for revenues from the development and sale of environmental credits totaling millions of dollars from wetland mitigation credits, depending on cost of restoration. Similar to the constructed wetland project already reviewed, the actual value of these revenues is highly uncertain, as the markets themselves are quite uncertain. Furthermore, the costs of restoration are both large and highly uncertain, which makes valuing a revenue-generating project even more difficult (Forest Trends, 2011). We guess that the revenue potential of such a project is between $0 and $10 million in present value terms. However, given the low level of assurance for these positive revenues, in order to remain conservative we are assuming no revenues from this project. As noted previously, another option would be to recalculate the financial value for both endpoints of the range.

2. Cost impacts
   - According to TNC & Dow, marsh protection reduces required levee costs by only $0.49 million in present value terms at their Gulf Coast site, assuming a 7% private discount rate (Table 10).

Table 10: Expected financial value of the coastal wetland conservation project.

		Financial Value	
	Revenues	**Cost Reduction**	**Added Costs**
Project 2 – Coastal Wetland/ Hurricane Mitigation	$0	$490,000	$0

Reputational Benefits (R)

1. Variety of public interests
   - Coastal wetland conservation involves five sectors of public interest including 1) water, 2) habitat, 3) soil, 4) biodiversity, and 5) climate change. Wetland construction will help improve water quality, habitat quality, and soil erosion. In the long term, coastal wetland conservation will help retain biodiversity and can mitigate some of the effects of climate change.

2. Intensity of public interest
   - The intensity of public interest is calculated by averaging the Gallup Poll percentage of respondents indicating "most concern" for the five public interests affected. In this case, water, habitat, soil, climate change and biodiversity have 49%, 45%, 36%, 36% and 35% of respondents indicating "most concern," respectively. We average these to determine the result: (49+45+36+36+35)/5 = 40.2 (Table 11).

Table 11: Reputational benefits from the coastal wetland/hurricane mitigation project.

	Reputational Benefits	
	Variety of Public Interests	**Average Percent of Public Indicating "Most Concern" in Gallup Poll (%)**
Project 2 – Coastal Wetland/ Hurricane Mitigation	5	40.2

Environmental Hazard/Risk Reduction (E)

1. Risk reduction potential
   - Wetland restoration has a known potential to reduce the risk of hurricane damage, primarily through its ability to dampen the worst storm surge effects. Wetlands have also been shown to mitigate flooding by temporarily storing and releasing storm water and by reducing flow intensity. (Arkema et al., 2013; Jones et al., 2008; Vymazal 2010). Wetland vegetation further provides significant soil retention and stabilization, particularly in riparian areas.

2. Risk characterization

    - This project provides both direct and indirect mitigation of environmental hazards. The explicit focus is on reducing the exposure to environmental risks from intense storms, more specifically the direct risk of flooding and physical damage to production facilities. The indirect risks are the interruption of business operations and potentially lost business opportunities.

3. Comparison to traditional infrastructure

    - Site assessments at Dow's Freeport site indicate that restoring an extent of wetlands marshland surrounding the facility reduces the required height of levees designed to protect the facility from flood damage. There is also indication that using restored and existing marshlands in combination with levees would be the most cost-effective option for mitigating hurricane risks for the facility, hence it is more effective (TNC & Dow, 2011) (Table 12).

Table 12: Environmental hazard/risk reduction potential for the coastal wetland/hurricane mitigation project.

	Environmental Hazard/Risk Reduction		
	Risk Identification	**Risk Characterization**	**Comparison to Traditional Infrastructure**
Project 2 – Coastal Wetland/ Hurricane Mitigation	Known (2)	Both direct and indirect (3)	More effective (3)

Policy and Regulatory Enabling Conditions (P)

1. Existence of policies

    - By searching "coastal wetland policy regulation" in the Federal Register, we found 13 results that relate to our project (February, 2014).

2. Scale of the policies

    - Numerous regulations apply to coastal wetland protection, some of which are listed below:
        - o The Coastal Wetlands Planning, Protection and Restoration Act. Enacted in 1990,

this law proposes to identify, prepare, and fund coastal wetlands conservation projects in Louisiana (USGS National Wetlands Research Center, n/d).

  - Section 404 of the Clean Water Act asks for federal permits before dredging or filling a wetland. Under the permits, companies are required to do mitigation measures, such as protecting or restoring a similar wetland elsewhere (EPA, 2013b)
  - A community-based program initiated by National Oceanic and Atmospheric Administration (NOAA) aims to enhance sustainable fisheries by funding fishery habitat protection projects, including coastal wetland protection (NOAA, 2005; NOAA, 2008).

3. Influence of the policies
   - There are <u>no</u> national policies directly affecting this project's central activity or purpose. Although the Clean Water Act is the most fundamental law regulating the nation's wetlands, it does not single out coastal wetlands, nor does it aim to reduce hurricane risks. Therefore, it is considered an indirect policy. The Coastal Wetlands Planning, Protection and Restoration Act, although a federal policy, only addresses coastal wetland conservation within Louisiana (Table 13).

Table 13: Potential policy and regulatory enabling conditions for the coastal wetland/hurricane mitigation project.

	Policy/Regulatory Enabling Conditions		
	Number of Policies	**Number of National policies**	**Do Direct National Policies Exist?**
Project 2 – Coastal Wetland/Hurricane Mitigation	13	3	No (0)

<u>Level of Knowledge and Activity in the Field (K)</u>

1. Depth of academic literature
   - Two related articles were found by searching "coastal habitats," and "hurricane mitigation chemical." Searches of other key words yielded no results.

2. Availability of data or tools to assess project feasibility
   - There is <u>one</u> publicly available tool to assess hurricane risk in coastal areas through

the Coastal Resilience Network (http://www.coastalresilience.org/). This publicly available tool assesses the coastal risk of storm surge and sea level rise. It allows users to see if their business locations have a high risk of being flooded by future natural hazards based on hurricane and sea-level rise scenarios.

3. Existence of projects
   - In this analysis, we find no active coastal habitat conservation project with specific goals of hurricane risk mitigation. We did find two review papers that are relevant to the field of interest:
     - Arkema et al., (2013). Coastal habitats shield people and property from sea-level rise and storms
     - Mclvor et al., (2012). Storm surge reduction by mangroves

   These two papers define the benefits of reducing risks from hurricanes by coastal habitats. However, they defined the risk broadly, and the specific benefits habitat conservation provided to businesses were not clearly stated. Moreover, neither of the projects provided cost estimates associated with conserving coastal habitats, thus it is difficult for businesses to use them in assessing project feasibility.

4. Existence of environmental groups and consulting firms as potential project partners
   - We find three potential groups or organizations to partner with. The coast resilience tool was developed by TNC, and the US Fish and Wildlife Service runs the coastal conservation service with the National Oceanic and Atmospheric Administration (Table 14).

Table 14: Level of knowledge and activity in the field for the coastal wetland/hurricane mitigation project.

	Level of the Knowledge and Activity in the Field			
	Depth of Academic Literature	**Existence of Publicly Available Data/Tools**	**Number of Projects**	**Number of Organizations for Potential Project Partners**
Project 2 – Coastal Wetland/Hurricane Mitigation	2	Yes (1)	0	3

5.7.2 Project 3: Forest Carbon Sequestration through Improved Management or Reforestation

This is a hypothetical forest project in the East Texas Piney Woods designed to increase forest carbon sequestration through changes in the rotation length. The project is 4,000 acres and follows the Climate Action Reserve's carbon offset protocol methodology (CAR, 2012).

Financial Value (F)

1. Revenue impacts
   - Based on our analysis of the CAR projects (CAR, 2014), the project's hypothetical size and productivity is 4,000 acres sequestering 50 tons of carbon/acre/decade. This results in the creation of 200,000 carbon credits a decade. In 2012, these credits sold for an average of $7.40/credit (Forest Trends, 2013), meaning this project could generate roughly $2,114,286 in present value terms over its life.
2. Cost impacts
   - A project of this size could be expected to cost several hundreds of thousands of dollars for management, administration and verification over its lifetime. We estimate a present value of roughly $300,000 based on those presented in Galik et al., 2009 (Table 15).

Table 15: Expected financial value of the forest carbon sequestration project.

	Financial Value		
	Revenues	**Cost Reduction**	**Added Costs**
Project 3 – Forest Carbon Sequestration	$2,114,286	$0	$300,000

Reputational Benefits (R)

1. Variety of public interest
   - Six public interest areas are affected by forest carbon projects, including 1) air, 2) habitat, 3) soil, 4) climate change, 5) biodiversity and 6) water. Reforestation can help improve water quality, purify air, and provide habitat. Over the long term, reforestation will help maintain the habitat biodiversity and decrease soil erosion. Engaging in large-scale forest carbon management can also help mitigate climate change.

2. Intensity of public interest
    - The intensity of public interest is calculated by averaging the Gallup Poll percentage of respondents indicating "most concern" for the five public interests affected. In this case, air, water, habitat, soil, climate change and biodiversity have 49%, 45%, 36%, 36% and 35% of respondents indicating "most concern," respectively. We average these to determine the result: (49+45+36+36+35+32)/6 = 38.8 (Table 16).

Table 16: Reputational benefits from the forest carbon sequestration project.

	Reputational Benefits	
	Variety of Public Interests	**Average Percent of Public Indicating "Most Concern" in Gallup Poll (%)**
Project 3 – Forest Carbon Sequestration	6	38.8

Environmental Hazard/Risk Reduction (E)

1. Risk reduction potential
    - The potential for forest carbon sequestration projects to reduce a specific environmental hazard or risk is unknown, primarily because this project does not directly relate to a facility or structure that could be damaged by environmental hazards.

2. Risk characterization:
    - Because no potential to reduce risk has been identified, the risk characterization is not applicable (N/A).

3. Comparison to traditional infrastructure
    - This project does not augment or replace a traditional infrastructure solution, hence this category is not applicable (N/A) (Table 17).

Table 17: Environmental hazard/risk reduction potential for the carbon sequestration project.

	Environmental Hazard/Risk Reduction		
	Risk Identification	**Risk Characterization**	**Comparison to Traditional Infrastructure**
Project 3 – Carbon Sequestration	Uncertain (1)	N/A (0)	N/A (0)

Policy and Regulatory Enabling Conditions (P)

1. Existence of policies
   - Searching the Federal Register for "carbon sequestration," and "reforestation," we find 16 related articles (February, 2014).

2. Scale of the policies
   - We find two national regulatory standards and programs that address forest carbon sequestration, including:
     - Carbon Sequestration Partnership Program (USDOE, 2009). Launched in 2003 by Department of Energy, this program establishes a national network for research related to carbon sequestration. The DOE has also publicized a notice of intent in requiring a Programmatic Environmental Impact Statement for the program (69 FR 21514).
     - Forest Land Enhancement Program: In 2003, the Department of Agriculture revised this program to encourage sustainable management on nonindustrial private forests. One of the measures provides cost-share assistance for landowners who practice carbon sequestration on their private lands (§230.40 36 CFR 230).

3. Influence of the policies
   - We find that national policies directly promote the project's central purpose. The Carbon Sequestration Partnership Program directly influences forest carbon mitigation projects since the main purpose of this program is to regulate and manage carbon sequestration (USDOE, 2009) (Table 18).

Table 18: Potential policy and regulatory enabling conditions for the forest carbon sequestration project.

	Policy/Regulatory Enabling Conditions		
	Number of Policies	**Number of National Policies**	**Do Direct National Policies Exist?**
Project 3 – Carbon Sequestration	16	2	Yes (1)

Level of Knowledge and Activity in the Field (K)

1. Depth of academic literature
   - Using the search words "carbon sequestration," "reforestation," and "United States," we find 10 academic articles in the first 50 results. Carbon sequestration effects of forest management are discussed from various points of view. For example, articles discuss differing rates of carbon uptake among tree species and how changing forest management methods affects carbon sequestration rates (Masera et al., 2002; Huang et al., 2004).
2. Availability of data or tools to assess project feasibility
   - We find several publicly available tools to measure the sequestered carbon. These include a tool for integrated valuation of environmental services and tradeoffs for carbon storage and sequestration (The Natural Capital Project, 2012a). Other organizations have also developed tools, including but not limited to the Food and Agriculture Organization of the United Nations (FAO, 2004), the Western Agricultural Economics Association (Antle et al., 2001), and Princeton University (Klaus et al., 2003).
3. Existence of projects
   - Our search turned up more than thirty carbon sequestration projects in the United States. Many projects, however, are done on a relatively small scale.
4. Existence of environmental groups and consulting firms as potential project partners.
   - We have identified 12 organizations involved in the field of forest carbon sequestration. Several environmental NGOs and academic institutions worked together to create the model in the InVEST tool as a part of the Natural Capital Project (The Natural Capital Projects, 2012). Many academic institutions have created carbon sequestration models (e.g., Canadell & Raupach, 2008; Keles & Baskent 2007,

Xu & Li, 2010). Governmental organizations such as USDA, EPA and USGS have departments studying forest carbon uptake (EPA, 2012b). A number of private companies such as Blue Source (www.bluesource.com) and Finite Carbon (www.finitecarbon.com) also help interested parties develop projects (Table 19).

Table 19: Level of knowledge and activity in the field for the forest carbon sequestration project.

	Level of the Knowledge and Activity in the Field			
	Depth of Academic Literature	Existence of Publicly Available Data/Tools	Number of Projects	Number of Organizations for Potential Project Partners
Project 3 – Carbon Sequestration	10	Yes (1)	30	12

5.8 Criteria Aggregate Scoring

The outcomes for each project's criteria determined during this assessment are compared against results for other the projects undergoing evaluation, receiving a score from zero to one, and scaled to the range of values for each sub-criterion across all projects under consideration. Sub-criteria are then weighted, with weights adding to one to determine a project's aggregate score for each criterion (i.e., F, R, E, P, and K). These aggregate scores contribute to the overall composite score of the project. The mechanics of aggregate scoring are illustrated using our example projects below.

Financial Value Aggregate Score (F)

We demonstrate in Table 20 below how the financial value aggregate score is determined. The italic values in the table represent values calculated from the other inputs in the table. Starting with the raw cost and revenue impacts determined in the previous sections, the minimum value and the range of values for each sub-criterion are established based on the suite of projects under consideration. Projects' sub-criterion values are then scaled linearly from zero to one, with one representing the most favored value. This scaling calculation takes the form[2]

$$Project\ SubCriterion_{Scaled} = \frac{Project's\ SubCriterion\ Raw\ Value - Minimum\ Value}{Maximum\ Value - Minimum\ Value}.$$

[2] In the equation, minimum and maximum values represent the sub-criterion minimum and maximum values for the set of projects being evaluated.

Once the scale sub-criterion values are determined, a weighted sum of the scaled values is calculated to determine each projects aggregate financial score. The calculation of the weighted sum takes the form

$$F = F_1 * wf_1 + F_2 * wf_2 + F_3 * wf_3,$$

with F_1, F_2, and F_3 representing revenues, cost reductions, and added costs, respectively. The w-variables are the weights applied to each sub-criterion. Weights, which should sum to one, represent subjective interpretations by the user of each sub-criterion's relative importance to the aggregate score, based on the company's needs. We used a similar weighted sum for each subset of criteria.

For example, it has been noted in the TEEB report and in conversations with TNC that revenues may factor more highly than cost impacts, so we have chosen to weight revenues more highly, comprising 55% of a project's aggregate financial score with the remainder of the weights split evenly between the cost measures at 22.5% apiece. However, one could imagine a more cost-averse organization giving a higher weighting to added costs. We will explore the issue of weighting more fully when looking at the projects' final composite score, where weighting also is a factor. Given our current weighting assumptions, the forest carbon project has the highest aggregate financial score (0.55), followed by the constructed wetlands project (0.45), then the coastal wetland/hurricane mitigation project (0.27).

Table 20: Aggregate scoring for the projects' financial values.

	Financial Value			
	Revenues	**Cost Reduction**	**Added Costs**	**Aggregate Score**
Project 1 - Constructed Wetlands	$0	$2,700,000	$0	
Project 2 - Coastal Wetland/Hurricane	$0	$490,000	$0	
Project 3 - Forest carbon	$2,114,286	$0	$300,000	
Min. Value	*$0*	*$0*	*$0*	
Value Range	*$2,114,286*	*$2,700,000*	*$300,000*	
Scaled Values				
Project 1 (Scaled)	*0*	*1*	*1*	***0.45***
Project 2 (Scaled)	*0*	*0.18*	*1*	***0.27***
Project 3 (Scaled)	*1*	*0*	*0*	***0.55***
Weights	0.55	0.225	0.225	

Reputational Benefits Aggregate Score (R)

Table 21 shows the aggregate scoring of reputational benefits for the suite of projects examined. The scaling of the two sub-criteria follows the same linear scaling methodology used for the financial aggregate score. The aggregate score is calculated using a weighted sum of the sub-criteria scores. We have given a 75% weight to the variety of public interest, and a 25% weight to the Gallup Poll average, as we feel that having an impact on a greater variety of interests is more indicative of a project's overall effect on reputation. Given our current weighting assumptions, the forest carbon project has the highest aggregate reputational benefit score (0.75), followed by the coastal wetland/hurricane mitigation project (0.58), then the constructed wetland project (0.25).

Table 21: Aggregate scoring for the projects' reputational benefits.

	Reputational Benefits		
	Variety of Public Interests	**Average Percent of Public Indicating "Most Concern" in Gallup Poll (%)**	**Aggregate Reputational Score**
Project 1--Constructed Wetland	3	43.3	
Project 2--Coastal Wetland/Hurricane	5	40.2	
Project 3 - Forest Carbon	6	38.83	
Min. Value	*3*	*38.83*	
Value Range	*3*	*4.47*	
Scaled Values			
Project 1 (Scaled)	*0*	*1*	***0.25***
Project 2 (Scaled)	*0.67*	*0.31*	***0.58***
Project 3 (Scaled)	*1*	*0*	***0.75***
Weights	0.75	0.25	

Environmental Hazard/Risk Reduction Aggregate Score (E)

Table 22 shows the aggregate scoring of environmental hazard/risk reduction for the suite of projects examined. The scaling of the sub-criteria follows the same linear scaling methodology used for the other criteria. The aggregate score is calculated using a weighted sum of the sub-criteria. We have weighted the risk identification variable the highest, at 50%, because we feel that identifying the potential to reduce a known risk exposure is the most important parameter of risk. We weight the comparison to traditional infrastructure at 30%, as it is a key indicator of the project's practical feasibility. Finally, risk characterization receives the remaining 20% weight. Given our current weighting assumptions, the costal wetland/hurricane mitigation project has the highest aggregate hazard/risk reduction score (1), followed by the constructed wetland project (0.1), with the forest carbon project receiving the lowest score (0).

Note that having a narrow range of risk-identification scorings available (0, 1, and 2), can be considered problematic, as each level indicates a marked increase in the effect of the scaled scores. However, we feel this is justified because a shift from none (0) to unknown (1) indicates a high magnitude of difference for this criterion, and allows for the possibility of an effect to be discovered in the future. The move from unknown (1) to known (2) is equally important, but not more so, because the effect of risk reduction depends equally on its risk characterization and its comparison to traditional infrastructure.

Table 22: Aggregate scoring for the projects' environmental hazard/risk reduction.

	Environmental Hazard/Risk Reduction			
	Risk Identification	**Risk Characterization**	**Comparison to Traditional Infrastructure**	**Aggregate Risk Score**
Project 1 - Constructed Wetlands	Uncertain (1)	N/A (0)	Less effective (1)	
Project 2 – Coastal Wetland/Hurricane Mitigation	Known (2)	Both direct and indirect (3)	More effective (3)	
Project 3 – Carbon Sequestration	Uncertain (1)	N/A (0)	N/A (0)	
Min. Value	*1*	*0*	*0*	
Value Range	*1*	*3*	*3*	
Scaled Values				
Project 1 (Scaled)	*0*	*0*	*0.33*	***0.1***
Project 2 (Scaled)	*1*	*1*	*1*	***1***
Project 3 (Scaled)	*0*	*0*	*0*	0
Weights	0.5	0.2	0.3	

Policy and Regulatory Enabling Conditions Aggregate Score (P)

Table 23 shows the aggregate scoring of policy and regulatory enabling conditions for the suite of projects examined. The scaling of the sub-criteria follows the same linear scaling methodology used for the other criteria. The aggregate score is calculated using a weighted sum of the sub-criteria. We have weighted the number of policies variable the highest at 50%, because we feel this is the strongest indicator of the regulatory climate. We weight the existence of direct national policies at 30%, as it is a key indicator of direct support for the project's core activities. Finally, the number of national policies receives a 20% weight. Given our current weighting assumptions, the constructed wetland project has the highest aggregate policy and regulatory enabling conditions score (0.8), followed by the forest carbon sequestration project (0.51), with the coastal wetland/hurricane mitigation project receiving the lowest score (0.2). Note that we again have a sub-criterion with a narrow range of scorings, the existence of direct national policies. We feel that using a binary measure for this is indeed justified due to the broader influence that national policies can have in incentivizing change.

Table 23: Aggregate scoring for the projects' policy and regulatory enabling conditions.

	Policy and Regulatory Enabling Conditions			
	Number of Policies	**Number of National Policies**	**Do Direct National Policies Exist?**	**Aggregate Policy Score**
Project 1 - Constructed Wetland	20	2	Yes (1)	
Project 2 - Costal Wetland/Hurricane	13	3	No (0)	
Project 3 - Forest Carbon	16	2	Yes (1)	
Min. Value	*13*	*2*	*0*	
Value Range:	*7*	*1*	*1*	
Scaled Values				
Project 1 (Scaled)	*1*	*0*	*1*	***0.80***
Project 2 (Scaled)	*0*	*1*	*0*	***0.2***
Project 3 (Scaled)	*0.4*	*0*	*1*	***0.51***
Weights	0.5	0.2	0.3	

Level of Knowledge and Activity in the Field Aggregate Score (K)

Table 24 shows the aggregate scoring of the level of knowledge and activity in the field for the suite of projects examined. The scaling of the sub-criteria follows the same linear scaling methodology used for the other criteria. The aggregate score is calculated using a weighted sum of the sub-criteria. We have weighted the number of potential partner organizations the highest at 40%, because they will likely be instrumental in bringing projects to fruition. We weight the number of projects and the depth of the academic literature equally at 30% each, as example projects and sound scientific models are important for successful project development. Note that the existence of tools was given a zero weight in this analysis, as the projects did not differ on this sub-criterion; however, had there been a difference, we would likely give it a 20% weighting, adjusting other weights accordingly. Given our current weighting assumptions, the forest carbon sequestration project has the highest knowledge and activity score achievable (1), followed by the forest carbon constructed wetlands (0.21), with the coastal wetland/hurricane mitigation project receiving the lowest score (0), given that there is relatively little information or activity for this project type.

Table 24: Aggregate scoring for the projects' level of knowledge and activity in the field.

	Level of the Knowledge and Activity in the Field				
	Depth of Academic Literature	**Existence of Publicly Available Data/Tools**	**Number of Projects**	**Number of Orgs for Potential Project Partners**	**Aggregate Knowledge Score**
Project 1 - Constructed Wetlands	6	1	10	5	
Project 2 - Coastal Wetland/Hurricane	2	1	5	5	
Project 3 - Forest carbon	10	1	30	9	
Min. value	*2*	*1*	*5*	*5*	
Value range	*8*	*0*	*25*	*4*	
Scaled Values					
Project 1 (Scaled)	*0.5*	*0*	*0.2*	*0*	***0.21***
Project 2 (Scaled)	*0*	*0*	*0*	*0*	***0***
Project 3 (Scaled)	*1*	*0*	*1*	*1*	***1***
Weight	0.3	0	0.3	0.4	

5.9 Composite Score and Prioritization

Now that we have input the data necessary for the criteria assessment and converted the raw evaluations to the appropriate scores, we can create a composite score for each project through a weighted sum of its criteria. The composite scores are relative scores that are meant to help prioritize the projects that have been assessed. Projects with higher scores indicate higher priority, while projects with lower scores indicate lower priority projects. As noted earlier in Section 5, the equation for determining the composite score takes the form

$$S = w_f F + w_r R + w_e E + w_p P + w_k K,$$

with F representing the financial value aggregate score, R the reputational benefit aggregate score, E the environmental hazard/risk reduction aggregate score, P the political and regulatory enabling conditions aggregate score, and K the level of knowledge and activity in the field aggregate score. Users can adjust the weights (w_x) associated with the five criteria that make up the composite score in order to better reflect their own contexts.

We have included two examples of the composite scoring system below to show how different weighting affects the outcomes. In example A, shown in Table 25, we give a 60% weight to the financial value score, equally dividing the weight among the other criteria at 10% apiece. We consider this to be a baseline-weighting scenario, as the bulk of most private companies' concerns likely fall into the financial category. Also, without knowing the mindset of a particular company, it is difficult to determine which of the other criteria they would value highly. Given this setup, the forest carbon sequestration project comes out as a clear winner, with a composite score of 0.56. This is followed by the constructed wetland project, 0.41, and the coastal wetland/hurricane mitigation project, 0.34.

Table 25: Example A – Composite scores weighted heavily on the financial criterion.

Composite Score (Example A)

	Financial Value	**Reputational Benefits**	**Environmental hazard/risk reduction**	**Policy and Regulatory Enabling Conditions**	**Level of Knowledge /Activity in the field**	**Composite Score**
Project 1 - Constructed Wetlands	*0.45*	*0.25*	*0.10*	*0.80*	*0.21*	***0.41***
Project 2 - Coastal Wetland/Hurricane Mitigation	*0.27*	*0.58*	*1.00*	*0.20*	*0.00*	***0.34***
Project 3 - Forest carbon	*0.55*	*0.75*	*0.00*	*0.51*	*1.00*	***0.56***
Weight	0.60	0.10	0.10	0.10	0.10	

In Example B, shown in Table 26, we have decided to reduce the overall importance of the financial value score to 30%. This allows room for the other components to be tweaked based on the businesses' concerns. For example, an organization highly concerned about the level of knowledge in the field or the possibility to mitigate environmental risks would give higher weights to these criteria. Lowering the financial value also allows for more equitable weights across all criteria. In Example B, the level of knowledge and risk reduction criteria each receive weights of 20%, whereas the reputational benefits and policy/regulatory conditions criteria receive 15% weights. Under this weighting, the forest carbon sequestration project remains at the top, with a composite score of 0.55. However, the coastal wetland/hurricane mitigation now comes in second with a composite score of 0.44, then constructed wetlands at 0.35. These examples show the versatility of the scoring framework to meet the needs and assumptions of a wide variety of users.

Table 26: Example B – Composite scores weighted less heavily on the financial criterion.

Composite Score (Example B)

	Financial Value	Reputational Benefits	Environmental hazard/risk reduction	Policy and Regulatory Enabling Conditions	Level of Knowledge /Activity in the field	Composite Score
Project 1 - Constructed Wetlands	*0.45*	*0.25*	*0.10*	*0.80*	*0.21*	***0.35***
Project 2 - Coastal Wetland/Hurricane Mitigation	*0.27*	*0.58*	*1.00*	*0.20*	*0.00*	***0.44***
Project 3 - Forest carbon	*0.55*	*0.75*	*0.00*	*0.51*	*1.00*	***0.55***
Weight	0.30	0.15	0.20	0.15	0.20	

5.10 Comparison of the Opportunities Examined

Financial Value

The financial effects of the first two projects, constructed wetlands for paper mill wastewater management and coastal wetland defenses, are similar in certain ways. They both reduce peripheral, non-core manufacturing costs. The constructed wetland projects may lead to reductions in regulatory costs, while the coastal habitat protection has the ability to mitigate some of the infrastructure costs pertaining to storm surge protection. In both cases, ecosystem service options are only likely to offset a portion of traditional infrastructure costs, as companies would have to maintain traditional infrastructure alongside ecosystem service technologies, given performance irregularities that have been present in pilot projects (ITRC, 2003).

The review of the forest carbon sequestration project revealed a completely different financial profile than the other two projects, largely because it is not undertaken as an alternative to a traditional solution. Rather, it is an entirely new undertaking that requires new investments not offset by reduced costs in other areas. All costs incurred for the forest carbon projects are new costs. This contrasts with the other two projects, in which the organizations were already assuming certain infrastructure investments within the course of their day-to-day operations — costs that the new projects are supplanting. However, as the forest carbon investments lead to the potential to enter a completely new market, they may be worthwhile over the long term if new revenues outpace costs.

Reputational Benefit

Both constructed wetlands for water purification and coastal wetland conservation for hurricane protection directly affect water quality and habitat interests. However, coastal wetland conservation projects are likely to affect a larger area, providing increased indirect benefits for soil, biodiversity, and climate change concerns. Carbon reforestation affects all measured public interests, given that forest preservation will indirectly help protect water, air, biodiversity, and climate change issues. Therefore, given our weighting assumptions, climate change mitigation through forest carbon management shows the highest potential to provide a reputational benefit, followed by coastal wetland conservation/hurricane mitigation, then wetland construction for water purification.

Environmental Hazard/Risk Reduction

When considering the potential of the three projects to mitigate the consequences of environmental hazards, it is clear that coastal habitat conservation and reforestation programs demonstrate the highest potential.. Both activities have greater risk mitigation potential than constructed wetlands, whose smaller footprint limits significant risk mitigation. When comparing the potential to reduce environmental risk between natural ecosystems and traditional solutions, considerable work must be done on a case-by-case basis to estimate the effectiveness of ecosystem service or natural capital methods against time-tested, traditional engineering solutions.

Policy and Regulatory Enabling Conditions

Following the logic we set up to judge the policy and regulatory enabling conditions, carbon sequestration through forestry receives the highest level of attention from the policy arena and hence has stronger enabling conditions. A stronger regulatory framework enables businesses to make wiser decisions with their ecosystem service investments and increases certainty that they will be recognized for their efforts. As for wetland related projects, constructed wetlands get more national regulatory rule-making attention than coastal wetland rehabilitation, so it achieves a higher score.

Level of Knowledge/Activity in the Field

Among the three projects, carbon sequestration through reforestation and waste reduction through constructed wetlands demonstrated relatively well-established levels of scientific knowledge. In contrast, hurricane risk mitigation through coastal habitat conservation is not well studied. This may be so in part because disasters rarely occur at the same location more than once in a short time. Moreover, realization of risk mitigation benefits from the habitat conservation project occurs over a long time period, providing fewer of the short-term benefits offered by other projects or investments..

In terms of the level of activity observed for similar projects, there were numerous forest carbon projects and constructed wetland projects. However, carbon sequestration projects seem to be engaged in by a more diverse set of organizations, such as environmental NGOs, universities, and private industry, while most of the constructed wetland projects were supported by governmental agencies. These results indicate that there is likely enough knowledge and interested partner organizations for businesses to engage in carbon sequestration projects. Our analysis indicates that forest carbon projects score highest of the three on Level of Knowledge/Activity in the Field criterion.

5.11 Discussion of Proposed Ranking System

Our assessment indicates that among the three examples, a forest carbon sequestration project is probably the most feasible. The field of forest carbon sequestration is well studied due to increasing concerns related to global climate change, and there is a great potential for such projects to provide a reputational benefit. Although financial returns for forest carbon investment are still limited by policy hurdles —namely the lack of a clear price on carbon—the level of financial uncertainty for such projects is lower than for the other two project types analyzed.

Among the various criteria considered, the most problematic to measure accurately is the reputational benefits from potential ecosystem investments because of the difficulty in clarifying how public sentiments towards different environmental concerns interact. However, we feel that using public polling data allows us to evaluate this inherently subjective criterion transparently. In our analysis, we measured public concern by the Gallup Poll, which we use as a proxy measure for reputational influence. In so doing, we assume that the reputational influence of a potential project increases when more people are interested in the related environmental issues, and that the Gallup Poll accurately captures the public interests. We believe that these assumptions may work for our purposes, but businesses may gain a better idea of the magnitude of reputational impact from more complex, non-market valuation techniques that attempt to place economic prices on a project's social values. However, such studies are difficult to undertake and are not without their detractors (Neill et al., 1994).

We have greater confidence in the accuracy of our other criteria. In some cases, we found the financial value of potential projects difficult to estimate due to the dearth of similar projects and a lack of publicly available information, but companies may have better access to relevant financial data. It is very important for business managers to have clear ideas of a project's financial costs and benefits to assess the project's feasibility, something that will have to be determined on a case-by-case basis. In contrast, scientific and policy indicators are readily determined using online sources.

Although there have been few feasibility studies of ecosystem service projects within business, studies indicate a strong business climate for carbon sequestration services—an indication that our results are fairly plausible (Lars, 2012). However, we are aware that these ranking results were based on our subjective assumptions, particularly when it comes to weighting the impact of the criteria within the scoring system. Users of this model will have to modify the ranking system based on their business objectives. Throughout this analysis, we have realized that professional knowledge of the risks and opportunities posed by the ecosystem exposure is crucial to accurately assessing project feasibility. Because most businesses are not very familiar with the field of ecosystem services, they may need professional assistance from other organizations with conservation experience such as environmental non-profits (e.g., WWF, TNC) or governmental organizations (e.g., USGS, EPA).

6 Conclusion

6.1 From Sustainability to Ecosystem Service Framework

By reviewing the history of both chemical manufacturing and forest products industries, we have found that there are undoubtedly economic and reputational incentives for both industries to incorporate ecosystem valuation techniques into their business models. Regulating services may be the most approachable services for the chemical industry. Specifically, the chemical manufacturing industry can take advantage of ecosystems to reduce waste pollution through wetland purification or forest carbon sequestration. The forest products industry stands to benefit the most from provisioning services because forests provide considerable amounts of timber and fresh water, but this industry can also benefit from climate regulation through carbon sequestration.

Although there has been increased focus on ecosystem service valuation in recent years, challenges remain that impede its widespread adoption. For example, the increasing globalization by multinationals makes it difficult to define a coherent environmental strategy. When combined with the proliferation of environmental NGOs competing for pre-eminence in this sector, the message of how businesses stand to benefit from ecosystem service engagement may seem fragmented, hence difficult to grasp. Companies are also inhibited from valuing such investments by the lack of well-defined scientific standards for evaluating and managing ecosystem services. This uncertainty, combined with the long payback periods that many ecosystem service projects require, could lead managers to be hesitant towards such investments. Our framework is designed to cut through this hesitancy, giving managers the tools they need to make a reasoned analysis of ecosystem opportunities.

6.2 Identification of Ecosystem Opportunities

In compiling a list of ecosystem service opportunities to be further examined in both chemical and forest products sectors, we used a matrix technique that could be easily replicated for almost any industry. As we have shown, this process also provides insight into the ways in which each sector benefits from ecosystem service investment, which varies considerably between sectors.

Ecosystem service opportunities in the chemical manufacturing industry are largely composed of innovative solutions to regulatory concerns or environmental hazards, while in the forest products sector they are mostly demand-driven, market-based initiatives that provide ancillary income streams. This difference seems to underlie the somewhat greater interest we noted from forest products firms as early adopters of ecosystem service valuation projects, given their ability to market new products and services in order to recover initial investment costs. Extrapolating from this trend, we predict that agriculturally intensive industries would have opportunities similar to those of the forest products industry to engage in ecosystem markets, given their similarly land-intensive nature. On the other hand, opportunities available to oil and gas or even heavy manufacturing industries may be more analogous to those found in the chemical manufacturing industry.

The process of identifying opportunities within these industry sectors also suggested reasons why current efforts to incorporate ecosystem values into business are the exception and not the rule. To date, ecosystem service valuation projects are expected to provide few financial returns, if any, and many companies perceive their level of exposure to ecosystem service risk as small. As we previously discussed in Section 4.7, these business expectations indicate a failure of policy and economics to adequately recognize and reward firms for their investment in ecosystem services. Although the science may support ecosystem service solutions as being similarly effective to engineered solutions, many regulations dictate or strongly suggest technologies that should be used to achieve regulatory thresholds, thus driving investment in infrastructure rather than ecosystem services. Markets also fail to reward good actors who are using innovative ecosystem service solutions to abate environmental damages. In order for ecosystem service opportunities to be more readily adopted by businesses, these failings must be addressed—likely through political intervention.

6.3 Conceptual Scoring Framework

The conceptual framework was designed to compare and contrast potential projects on five different criteria. They are financial value, level of knowledge/activities, policy and regulatory enabling conditions, reputational benefits, and environmental risk mitigation benefits. In this analysis, we assumed that financial value was the most important variable because ecosystem-related projects have to be financially feasible to be considered by business sectors. The level of knowledge/activity in the field was also very important, and because ecosystem services are a new concept to many companies, partners with professional knowledge would be crucial to achieve project success. Policy and regulatory enabling conditions become important not only for evaluating a project alongside traditional infrastructural solutions, such as a waste treatment plant, but also for creating conditions for businesses to capture value when the project does not have a strong correlation with their traditional business model, such a forest carbon sequestration. As such, these enabling conditions can have a secondary influence on financial values. In contrast to the first three variables, reputational benefits and environmental risk mitigation value are relatively difficult to measure. Our use of the Gallup Poll as a proxy measure of reputational influence may not capture public interest accurately, but other techniques such as nonmarket valuation would be too difficult for this sort of analysis, and their accuracy is debatable as well. Environmental risk mitigation tends to be a long-term effect, and consequently it may not be heavily valued in a business perspective.

6.4 Strengths and Limitations of the Study

In the first part of this study, the interactions between ecosystem and business sectors (chemical and forestry business) were analyzed by a literature review. The information from this analysis was unique and useful for the chemical and forest products industry because few studies had assessed ecosystem-related benefits for entire business sectors. This strength also applies to the second part of this study: identification of ecosystem-related opportunities. In this process, the opportunities were primarily evaluated from a business perspective, not an environmental point of view. We believe this perspective represents an effective approach for businesses to inform themselves about the value of ecosystems and ecosystem services to their companies. One of the weaknesses in the first two parts of our analysis was the lack primary of data from businesses because of information accessibility issues. Although we reviewed company sustainability reports, because the publicly available information from companies tended to be vague, it was difficult for us to identify the reasons that businesses are not considering ecosystem services.

The third part of this study was construction of a conceptual framework to assess identified opportunities. The flexible characteristics of the conceptual framework allow business operators to compare potential projects based on their own needs. Once the user adjusts the framework, projects are compared transparently through an organized scoring structure. Therefore, it works well to compare potential ecosystem related projects. However, the conceptual framework is predicated on a business's pre-existing desire to seek ecosystem service solutions. It was not designed to generate that initial interest in ecosystem service solutions, which instead must be driven by motivated individuals or stakeholders. This is an area where organizations like TNC must work to generate interest. Once that interest is in place, the framework can be used to uncover ecosystem-business interactions and opportunities. Finally, we only apply the framework to two industries in this study, though we see it as applicable for a wide range of business sectors.

6.5 Recommendations

One of the primary obstacles preventing the widespread realization of ecosystem services by private industry is the lack of examples in which investing in ecosystems has proven to be successful. In addition to the small portfolio of active projects, there is significant corporate skepticism that investing in ecosystems is financially viable. Business managers are therefore hesitant to pursue ecosystem investments due to significant uncertainty in the expected outcomes of various opportunities (WRI, 2012; TEEB 2012). This uncertainty, coupled with the difficulty of assessing the type and quantity of benefits ecosystems provide, makes businesses reluctant to consider ecosystem investments (WRI, 2012). While the framework we have developed in this paper does not completely remove this uncertainty, it does provide companies an easily accessible tool to recognize and make common-sense evaluations of the range of ecosystem service investments available to them. We believe these tools can help recognize and minimize uncertainty, indicating which investments are most likely to benefit the company. This, in turn, can lead to an increase in the number of example projects, increasing overall interest from business leaders. We recommend the creation and application of practical tools, such as ours, to help move the consideration of ecosystem service investment from the peripheral to the mainstream.

More generally, the level of ecosystem service comprehension in business and the analysis required to develop our scoring framework indicate the importance of both knowledge and political backing to drive ecosystem service investment. However, companies may lack the ecological knowledge themselves to conduct the analyses necessary to evaluate the potential to benefit from ecosystems (WRI, 2012). In addition, government programs to support private industry ecosystem service investments may be lacking or tentative (WRI, 2012) Therefore, developing a venue for communication between scientists, business managers, and policy makers is critical for the exchange and reinforcement of the scientific underpinnings of ecosystem service investments. If this takes place, policymakers will be more likely to support ecosystem service approaches, and businesses more comfortable in undertaking them.

Enacting government systems to financially support and acknowledge the value of investing in ecosystems would reduce the risk and uncertainty private companies face when they consider such investments. Business managers will likely be much more willing to pursue ecosystem investment options if they face less risk should the project fail. Such incentives could come in the form of tax breaks or regulatory requirement adjustments to reflect the benefits captured from ecosystem investment. A successful example of such government support is California's AB-32 carbon cap and trade policies, which incentivize business investment in ecosystem-based greenhouse gas offset projects—including forest carbon and inventive agricultural waste management techniques—allow carbon credits to satisfy state permitting requirements (California, 2006). To date, California has issued over two million "offset credits" to such ecosystem-based projects (Cal EPA, 2014), equating to tens of millions of dollars in revenues for project participants (Forest Trends, 2013).

As the number of successful ecosystem investments grows, the skepticism many business managers have towards the viability of such investments will be resolved. Mangers will benefit from applying the appraisal framework we have developed, as it enables companies to take the initiative and realize the best investment opportunities to pursue. Through applying our framework, business managers can evaluate the potential of a project or ecosystem investment at a high level. The wider the variety of projects this framework is applied to, the more its strengths and weaknesses will become apparent. Ultimately, we recommend that The Nature Conservancy distribute the framework to business council partners, collaborating to test and hone its effectiveness. Applying the framework to companies outside of the forest product and chemical manufacturing industries will reveal how effective the framework is at guiding judgment on ecosystem investment potential. Through the application of the model, mangers will reveal flaws in the framework and make suggestions on how to improve upon it to meet their needs. We hope that it will encourage the proliferation of ecosystem investments within private industry.

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8 Appendix

Table 27: A description of risks and opportunities identified in the chemical industry.

Category	ID	Specific Risk or Opportunity	Description
Air Quality and Climate	1	Reforestation air quality benefits	Forest ecosystems provide valuable benefits for the chemical industries. First, trees are capable of removing various air pollutants such as nitric oxides, sulfuric oxides (causes of acid rain), ozone, and particulate matter or even heavy metals (Li et al., 2013; Qui et al., 2009; Dow & TNC, 2011). It is also well known that trees can absorb greenhouse gases to mitigate climate change risks (MEA, 2005). Moreover, root system of a tree can hold much larger amount of water than bare soil (Anderson et al., 1976), which can provide a stable source of freshwater in a long term.
	2	Release of greenhouse gas	Chemical manufacturing processes create various gaseous pollutants. For example, greenhouse gases such as CO_2, N_2O, and CH_4 are produced in the feedstock and energy business sector (Cefic, 2011).
	3	Release of toxic gases	According to EPA's toxic release inventory, chemical manufacturing can release various toxic gases, including ethylene, chlorine, propylene, vinyl chloride, benzene, chloroprene and much more.
Water	4	Constructed wetlands for purification	The purification function of wetlands has been long recognized by scientists. Scientists have designed various types of artificial wetlands to mimic the natural purification process, including free-water, vertical and horizontal wetland systems. Different technologies can be combined to reach the desired pollution abatement level (Vymazal 2010). Dow Chemical Company has a wetland project to treat organic chemicals and plastic fibers in Seadrift, Texas (Dow et al., 2013).
	5	Eutrophication	Eutrophication is a water quality problem caused by excess amount of nutrients such as nitrogen and phosphorus (USGS, 2013). The rapid growth algae population consumes dissolved oxygen, which makes the water uninhabitable to other aquatic organisms (USGS, 2013). A common cause of eutrophication is the usage of synthetic fertilizers, which are one of the main products of the chemical industry.
	6	Freshwater scarcity	Due to the extreme weather events caused by climate changes and excessive use of ground water, the scarcity of freshwater is projected to become severer and more

Category	ID	Specific Risk or Opportunity	Description
			frequent (IPCC, 2013). The chemical manufacturing industry requires significant amounts of water, thus the freshwater scarcity is very influential (Dow & TNC, 2012).
	7	Release of water pollutants	The chemical manufacturing industry releases various water pollutants to streams during the production process. Pollutants can include organic chemicals, hydrocarbons from plastic production, and metal compounds (e.g., lead, mercury, zinc, nickel, manganese, and chromium) (TRI, 2011; Khan et al., 2000).
Soil	8	Phytoremedia-tion, a soil mitigation approach	Phytoremediation is a water and soil remediation approach that use plants' roots to transfer pollutants from natural ecosystems (Meagher, 2000). Dow Chemical Company has experience with this water remediation method in Midland, Michigan (Dow et al., 2013).
	9	Synthetic polymers technology for soil mitigation	This chemical technology increases the water holding capacity of the soil to increase the productivity of vegetation (WBCSD, 2010). It is still a developing technology and only applied in agricultural lands. However, increasing productivity of vegetation might also increase ecosystem services-related activities such as air purification and reduction of greenhouse gases.
Conservation	10	Habitat conservation	The frequency of coastal flooding from extreme weather events is suggested to be increasing due to climate change (IPCC, 2013). The damage to infrastructure from natural disasters can significantly influence business operations (Tierney, 2006). Studies have shown that vegetation in the coastal wetland habitat creates a natural buffer to protect infrastructure from the floods (Arkema et al., 2013; Jones et al., 2008). Moreover, some chemical companies are active on conservation projects on other types of landscapes for biodiversity preservation (Dow, 2012c; LynodellBasell, 2012). These projects might be an effective approach to developing an environmentally friendly cooperate image.
Market	11	Energy price	Chemical manufacturing is very energy intensive, thus is greatly influenced by the price of energy sources (Dow, 2012b; Eastman Chemical Company, 2013). The diversification of energy sources such as solar, wind and biofuel might increase operational stability against the fluctuation of energy prices.
	12	Renewable chemical market	The renewable chemical market refers to the chemicals that are produced with renewable feedstock. For example, agricultural waste used as biomass, microorganisms used

Category	ID	Specific Risk or Opportunity	Description
			as waste treatment media and renewable alcohol (Sunita, n.d.).
Regulation	13	Clean Air Act	This regulation enforces quality standards for air pollutants. Chemical manufacturing businesses release various pollutants (see #17), thus are highly affected by this regulation. Nitrogen oxides and sulfuric oxides are two main chemicals that the Clean Air Act regulates, and are common bi-products in chemical manufacturing (EPA, 2011b).
	14	Clean Water Act	Similar to the Clean Air Act, this regulation provides standards for water quality (EPA, 2013b). Under this regulation, the chemical manufacturing facilities cannot exceed the standard amount of liquid pollutant release, which causes additional financial costs. Among different water pollutants, the chemical industries are especially responsible for petroleum-based hydrocarbons and heavy metals (see #17).
Other	15	Brand equity as a reputational benefit	Research shows that in the chemical product market, where customers often cannot tell the quality difference from the appearance, a company's reputation significantly influences a customer's shopping decision (Tuominen,1999). Chemical companies may gain brand equity from a positive environmental reputation and improve their market share.
	16	Cooperation with environmental organizations	Cooperating with environmental organizations is one emerging approach for chemical companies to receive technical support (Beder, 2002). For example, Dow Chemical Company is actively working with The Nature Conservancy on three ecosystem service-related pilot projects (Dow et al., 2013).
	17	Environmental catastrophes	Environmental catastrophes may put a chemical company's reputation at risk. For example, the market value of Exxon dropped by billions of dollars after its Valdez oil spill (Beder, 2002).
	18	Responsible Care, an organization for sustainability	Responsible Care is a global initiative with the mission to achieve sustainable development in chemical industry by improving health and safety conditions in the industry (ICCA, 2009). Currently, 53 chemical companies are members, voluntarily devoting their social responsibility to the public (ICCA, 2009).
	19	Vegetative buffers for noise mitigation	A number of studies have shown that tree buffers have the function of noise mitigation, aesthetic value and creation of habitat (Georgia Forestry Commission, 2008; USDA, 2008; Beal J, n.d.). Although various types of trees could

Category	ID	Specific Risk or Opportunity	Description
			be used as noise buffers, evergreen trees providing leafy-buffers year-round are superior to deciduous trees due to the important role leaves play in mitigating noise pollution (Georgia Forestry Commission, 2008). Further description is provided in the following section.

Table 28: A description of risks and opportunities identified in the forest industry.

Category	ID	Specific Risk or Opportunity	Description
Air Quality and Climate	1	Air quality benefits	Timberlands, including urban forests, are being increasingly managed to maximize air purification benefits. Through photosynthesis forests have the ability to clean the air by removing various types of air pollutants including nitrogen, sulfuric, and carbon oxides, various heavy metals, and particulate matter. (MEA, 2005; Dow & TNC, 2011; Li et al., 2003).
	2	Bark beetle outbreaks due to climate change	In the last 20 years, climate change has increased the distribution and influence of parasitic beetles, causing high mortality rates in large areas of national and private forests. In the 1990s large areas of Alaska, particularly the Kenai peninsula, experienced record Spruce Beetle (*Dendroctonus rufipennis)* mortality rates totaling more than 6 million acres (Alaska Department of Forestry, 2013). Since the late 90s, more than 4 million acres of National Forest in the Rocky Mountains have been killed by the Mountain Pine Beetle (*Dendroctonus ponderosae*) (USFS, 2012).
	3	Changing species ranges due to warm temperatures	In response to climate change and warming temperatures, many species are beginning to exist in areas they previously did not. As species begin to migrate into new areas they may outcompete native species. Changes to the historical range of species can lead to issues of scarcity due to the effects of invasive species and extirpation of native species due to changing abiotic conditions.

Category	ID	Specific Risk or Opportunity	Description
	4	Climate change	Climate change significantly affects businesses in real estate, timber management, pulp & paper, and wood products. Climate change is likely to produce significant natural hazards that can physically damage businesses and cause significant operational damage due to issues of scarcity and raw materials. Some of these natural hazards can be mitigated through investing in ecosystem services (e.g. wetland and forest protection).
	5	Climate-driven growth effects on trees	Climate change, more specifically warmer average temperatures, influences growth rates of many trees by extending the growing season. This can increase the average yearly volume growth in some areas, making timberlands more productive.
	6	Fire risks caused by climate change and human impacts	Forests have always been at risk of being damaged by fire. Climate change and human impacts are changing the nature of fire risk in ways that managers must adapt to (Smith et al., 2007).
Water	7	Constructed wetlands for water purification	Constructed wetlands are an inventive way to help manage water pollution originating from pulp and paper mills. This is discussed further in Section 4.1.2 (Choudhary et al., 2011).
	8	Release of water pollutants	Pulp & paper production facilities use large amounts of water, and their effluents can be high in nutrients, organochlorine compounds, and bleaching agents (Choudhary et al., 2011).
Soil	9	Soil nutrient depletion by removing wood residuals from forests	Wood pellet industries removing all wood residuals from forests are blamed for depleting soil nutrients (Qian, 2013).
Conservation	10	Competition between forest product firms and conservation groups	Conservation groups have acquired and continue to acquire forest lands, which oftentimes are removed from active forest management. This may reduce the land base available for forest product firms to source wood, possibly leading to supply constraints. On the other hand, forestland owners do have opportunities to sell land to conservation interests, if the need arises (Bliss et al., 2008).
	11	Conservation easements (forest owners	Increased placement of conservation easements presents both a risk and opportunity to forest product firms. Conservation easements that do not allow for the

Category	ID	Specific Risk or Opportunity	Description
		sell certain development rights)	harvesting of timber may lead to supply constraints. However, working forest conservation easements are also common, whereby the forest owner sells certain development rights while retaining the right to harvest timber. Sale of easements can provide additional income for the forest owner (Ellefson et al., 2004; Smith et al., 2007).
	12	Endangered species act/species management	Forests provide habitat for a diverse array of plant and animal species, a number of which are endangered. Proper forest maintenance can maintain and enhance habitat for these species, and possibly allow for the sale of biodiversity credits (Forest Trends, 2011).
	13	New genotypes (rapid growth, disease resistance)	The frequent occurrences of natural hazards increase the risks of wood disease for forest industries. Opportunities exist for investigating new genotypes for rapid growth and disease resistant species (Dougherty & Dougherty forestry services, 2014)
	14	Wood disease spread (frequent occurrences of natural hazards)	The frequent occurrences of natural hazards increase forest industries' risk of wood disease. Opportunities exist for investigating new genotypes for rapid growth and disease resistance species. (Dougherty & Dougherty forestry services, 2014).
Market	15	Biodiversity markets (compensatory mitigation and conservation banking)	As biodiversity and ecosystem functionality become more valued, compensatory mitigation and conservation banking programs continue to grow. Currently, the biodiversity markets in the U.S. are dominated by wetland compensatory mitigation and conservation banking programs. These account for the greatest volume of payments and area to the global biodiversity market, bringing in USD 2.0-3.4 billion and over 15,000 hectares (37,700 acres) annually. US mitigation banking is still showing increases, with a total of 1,044 active and sold-out wetland, stream and conservation banks (Madsen et al., 2011).
	16	Bioenergy demand effects on wood price	Increasing demand for wood bioenergy diverts wood from traditional uses. This puts pressure on wood product manufactures, forest managers, and even wood product consumers. Recent studies show significant short and long-term effects in timber price (Abt et al., 2012).
	17	Forest biofuel demand and effects	There is some concern that collecting residues for biofuels can have negative environmental consequences, and that the increased demand for wood

Category	ID	Specific Risk or Opportunity	Description
			biofuels can have crossover effects into other markets (e.g., decreasing the availability of wood fiber for producing pulp and paper). This debate is ongoing, and outcomes need to be monitored so forestland holders know how to respond (Siceloff, 2013).
	18	Forest carbon markets	Places like EU, California and China have favorable policies for establishing carbon markets, which is bringing opportunities for forestry firms on both sustaining local forest ecosystem and maintaining global climate stability. For example, China has put forward several policies to promote its carbon market and other carbon sequestration projects to encourage solutions for treating air pollution and protecting forests (Finite Carbon, 2013; Nielson, 2011; Siceloff, 2013).
	19	Water quality markets	The EPA has developed a water quality trading system to control water pollution and protect watersheds by trading pollution reductions among enterprises to help companies alleviate their high environmental costs (EPA, 2008).
Regulation	20	Clean water act (erosion/runoff)	The Clean Water Act significantly affects businesses in timber management, pulp & paper, and wood products. Opportunities to comply with Clean Water Act standards may be accomplished through investing in ecosystem services (e.g. constructed wetlands, wetland protection).
	21	Federal & state forest practice guidelines/ increased regulation	Many states and the federal government have regulations addressing forest management practices on public and private lands. These laws can restrict harvesting near streams, require management of erosion, and place restrictions on road building, to name a few of their requirements. Generally, increased stringency of such measures cuts into profits, driving certain lands to be financially unfeasible for harvest (Ellefson et al., 2004). Any increase in such restrictions poses risks for forestland holders (Potlach, 2012; Weyerhaeuser, 2012). But these laws may also present opportunities to engage in environmental markets, such as water quality trading and biodiversity credits.
Others	22	Competition between forest conservation initiatives and agricultural	If agriculture becomes more profitable then it is likely to compete more with forest conservation initiatives. This competition will likely influence landowners who are motivated by profit the most. Conversely, if agriculture becomes less profitable, landowners will

Category	ID	Specific Risk or Opportunity	Description
		activity	likely convert back to timberlands if possible.
	23	Competition with other operational segments (real estate) within one firm	Some forest product firms such as Weyerhaeuser are in multiple businesses, including real estate development. Should they develop or sell off a tract of forestland, this reduces the land base available for firms to source wood, possibly leading to supply constraints (Bliss et al., 2008).
	24	Conversion of agricultural lands to forests	Marginal agricultural lands that are no longer in production may present an opportunity for acquisition and conversion to forestlands (Smith et al., 2007).
	25	Land quality/price relationship	Quality of land will directly influence price, which will affect forest practices on timber management. Also, it will change the competition between forest and other segments of practices like agriculture. These new opportunities in real estate lie in previous closed stands like stewardship contracts. (Thorsen, 2010; Siceloff, 2013).
	26	Recreation permits (hiking, hunting & fishing)	Many wood products companies in the EU such as Sveaskog have tried to benefit from conserving forests by developing their recreation functions such as hiking, hunting and fishing. By incorporating these nontimber services into their decision making models, they benefit and help value the ecosystem services (Sveaskog, 2012).
	27	Responsible development/ community involvement	Developing countries like Brazil and China have incorporated forest protections into other social problems like poverty. They promote sustainable community development by encouraging the locals to harvest other products rather than destroying forests (Scherr et al., 2006).
	28	Sustainable certification for reputational benefits	In order to track illegal logging among countries, sustainable certifications are widely promoted by international organizations, seeking a chance to implement them in countries. These certifications will regulate the timber management process in forestlands and guarantee a sustainable supply chain for wood products. In one aspect of these industries, adopting sustainable certification will help them to build the enterprises' images.) (FSC, n.d. A; UNECE/FAO, 2012).