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Valuing Ecological Services of Peri-Urban Open Spaces: A Case Study of the West Tatnuck Neighborhood of Worcester, Massachusetts

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VALUING ECOLOGICAL SERVICES OF PERI-URBAN OPEN SPACES:

A CASE STUDY OF THE WEST TATNUCK NEIGHBORHOOD OF WORCESTER, MASSACHUSETTS

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ABSTRACT

Ecological services are the goods and services provided by an ecosystem that help sustain human life. Traditional economic valuation lacks the flexibility to account for all these services. Ecological economics uses different approaches to account for these services and provides a more accurate value of open space. A study of the West Tatnuck neighborhood of Worcester, Massachusetts highlights the differences between the schools of thought and shows the value of ecological services to an urban area.

EXECUTIVE SUMMARY

INTRODUCTION

There are many ways of valuing open spaces. Among the two dominant schools of thought, traditional economy generally recognizes fewer natural services than ecological economics and thus the latter provides a more complete value of a parcel of open space. The purpose of this project was to compare the value of the land from both sides of this conflict. A key finding of this research was that open spaces are typically undervalued. A more holistic value derived from the ecological economic perspective would make a better case for conservation.

Through a case study of the West Tatnuck neighborhood of Worcester, Massachusetts this project examined the two valuation approaches. The study area is a peri-urban neighborhood with a mixture of forested open spaces and residential blocks with tree lined streets. For this project, West Tatnuck will be defined by the area between MA-Route 122, the Worcester city limit, and all parcels on the east side of Tory Fort Lane. While much of the open space is protected a good portion is zoned for development.

BACKGROUND

Ecological services are the goods and services provided by an ecosystem to help sustain human life. Of the many possible ecological services, only a few were examined. The traditional or economic viewpoint focuses on services have market value and include raw materials, food production, recreational and cultural values. The ecological economics view is much broader. Services valued by ecological economics are categorized (in Table 1) into soil based and regulatory; soil based services include erosion control, soil formation and nutrient cycling while air filtration, micro climate regulation, noise reduction, overland flow mitigation and waste treatment are part of the regulatory services.

Table 1: Service Classification

Regulatory	*Soil Based*	*Economic*
Air Filtration	Erosion Control	Aesthetics
Climate Regulation	Nutrient Cycling	Food Production
Noise Reduction	Soil Formation	Raw Materials
OLF Mitigation		Recreation
Waste Treatment		

There are several types of value that can be prescribed to ecological services. The value from the perspective of the government cost was assessed, but some values, such as microclimate regulation, were more beneficial to the individual land owner. In both cases, indirect economic valuation methods such as avoided cost, replacement cost and hedonic pricing, as outlined by de Groot, Wilson, and Boumans (2002), were used. Avoided cost is the amount the city doesn't have to spend because the natural system takes care of it whereas replacement cost is more specific to the installation and maintenance cost involved in setting up gray infrastructure to replace the work of the green infrastructure. Hedonic pricing is based on the effect open spaces have on the real estate value and consequently the revenue generated from property taxes of the surrounding houses. Another method of valuing ecosystem services is "willingness to pay" which is defined by Bockstael, Freeman, Kopp, Portney, and Smith (2000) as "how much individuals would be willing to give up in other things to obtain this outcome" (p. 1387). This can be accomplished by doing surveys in the specific area and is best saved for specific services such as recreation where the other methods are insufficient. Because of the varying unit time of the individual services, the worth of the land was examined over a period of thirty years. The aforementioned information represents the theory behind this project. Next, the practical application of this information will be investigated

FINDINGS: CONVENTIONAL ECONOMIC VALUE

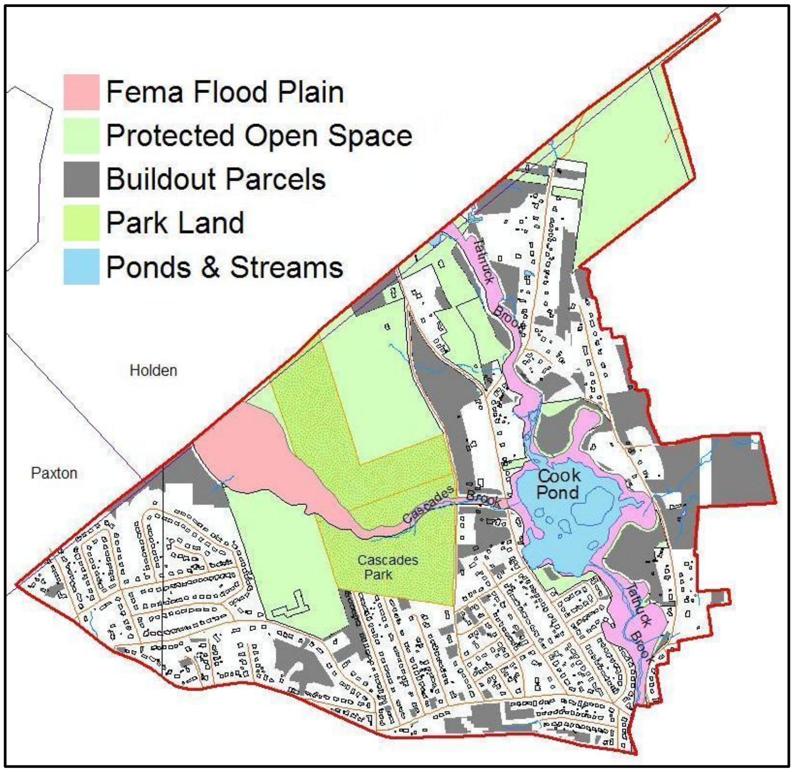
Two economic values were explored in this project. The "current" economic value is the typical value of open spaces derived from the traditional viewpoint of considering only those services that benefit the individual. The "maximum" economic value is calculated from the tax revenue generated from full development. The first finding of the project concluded that the potential revenue from the region is *greater* than currently valued services.

Table 2: Net Tax Revenue

Taxes from CMPRC Lots	$	22,524,210.00
Schooling for CMRPC Lots	$	(7,274,397.00)
Taxes from Group Projection	$	68,170,620.00
Schooling for Group Projection Lots	$	(33,787,660.00)
Cost of New School in District	$	(17,850,000.00)
Net Tax Revenue	$	31,782,773.00

The current economic value (Table 2) of the study area, which is mixed between development and open space, is less than the value derived if the area was to be fully developed. The Central Massachusetts Regional Planning Commission (CMRPC) estimates that 339 additional units could be built in West Tatnuck if needed. The locations of these plots are shown in gray in Figure 1. Protected open space makes up a significant portion of the study area which was not included in the CMRPC data set. An estimate for the number of new units in the protected area was calculated by using the zoned RS-7 minimum lot size of 7,000 square feet and the total square footage not falling in the FEMA flood plain. The revenue generated from the additional 1365 units, in terms of property tax over a period of thirty years, was assessed using Worcester's current tax rate of 1.21% and the average house value of $183,000. The city would also have to spend the money generated in infrastructure costs the largest of which would be education costs for 573 new children that would include building at least one new school. Without accounting for other gray infrastructure costs, the net amount gained from maximum build out was calculated to be $31,782,773

Figure 1: Build-Out Map



The current economic value of the area comes from four services. The value of homes that are located in or abut natural open spaces would be greater than houses in less aesthetically pleasing areas. The houses in West Tatnuck were considered to be 22% more valuable because of their proximity to the Cascades, Cook's Pond, Tatnuck Brook, and other forested areas. There are 100 such houses in the area which would generate a total of $1,461,750. Through a regiment of sustainable harvesting the timber in West Tatnuck could realistically be cut three times in thirty years. A combined 104.5 acres of the region has sustainability practices in place. By extrapolating this into West Tatnuck, the 314 harvestable acres could yield $379,129.20. The total number of passive recreation (fishing, hiking, and biking) visits per year to West Tatnuck is approximately 2,500 according to the Greater Worcester Land Trust. According to National Park Service, U.S. Forest Services, and Illinois Parks and Recreation Department, the average willingness to pay for these activities is $4 per person which places the recreational value at $300,000. The sap production in West Tatnuck is provided by approximately 504 sugar maples of adequate size in the area which would produce $30,240 of raw sap.

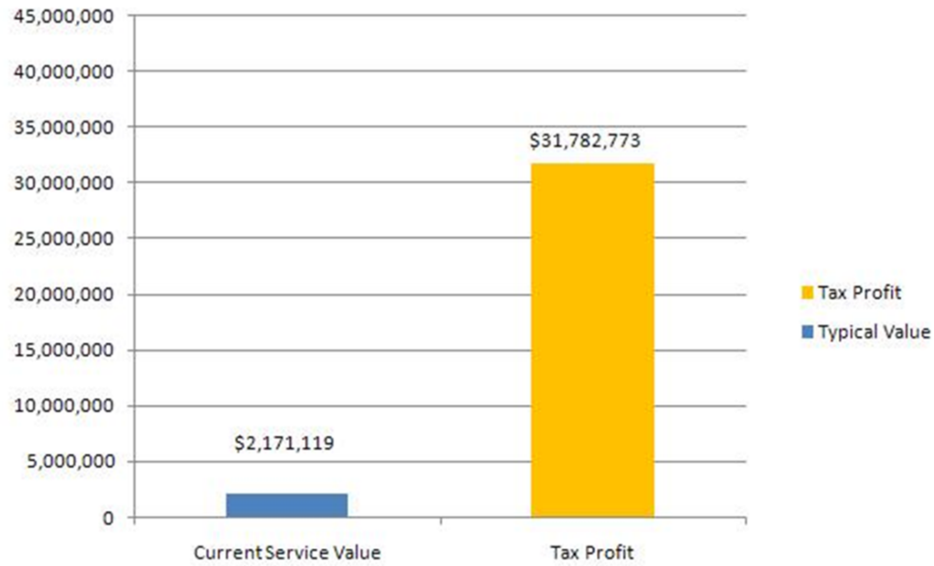
- Cultural Value: $ 1,461,750
- Raw Materials: $ 379,129
- Recreation: $ 300,000
- Food Production: $ 30,240

  Total: $2,171,119

The total value of these services is $2,171,119. This is less than the gross amount gained from property taxes, $31,782,773 and implies that development is the better option for the city of

Worcester (Figure 2). The services mentioned above are the maximum value land use planning would assess for the open space. However, this value is incomplete because it fails to account for all the ecological services offered by the open spaces of West Tatnuck. These services combined with the four mentioned above provide a more comprehensive value to the open spaces.

Figure 2: Conventional Economic Valuation



Findings: Ecological Economic Value

The full value of the open spaces of West Tatnuck is derived from the combination of typical value and two other categories of services—soil based and regulatory. If the typical value, which was previously calculated to be $2.17 million and the full value were closer together, then the additional categories services could be considered negligible and the economic valuation could be assumed as correct. In the particular case of West Tatnuck there is a large difference between the two pointing to the conclusion that the open space is typically undervalued.

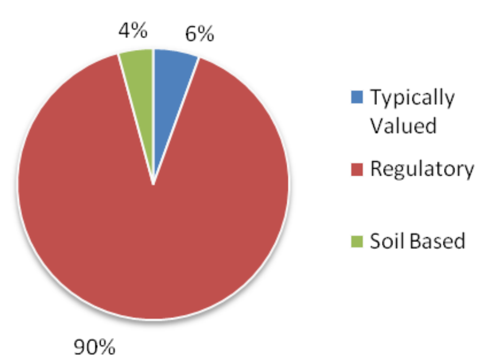
Regulatory services were valued at $35,409,363. The real estate value of houses under the flight paths decreases by 0.5% per decibel of ambient noise over 55dB (Nelson, 2003). The homes in the area have reduced noise pollution because of the forested areas. Without this vegetation absorbing the sound, the area would be afflicted with the ambient noise of 60 dB (Kneeland Airport Master Plan Update, 2005) and suffer from a reduction of 2.5% in real estate value which translates to a loss of $21,632,604 of tax revenue for the city of Worcester. The air filtration calculator from CITYgreen requires the model of a city. The city of Worcester was not included in this and thus the model of the city of Providence was used instead. The total value of air filtration was $2,008,659. Climate regulation was valued by measuring the amount the average resident of West Tatnuck saves in energy costs. According to a study by MIT, the average house saves about 20-25% if it is surrounded by trees such that it provides shade in the summer and blocks the cold air in the winter. A conservative estimate of 15% was used for the homes of West Tatnuck since an ideal situation is not applicable to all the houses. According to

Energy Star (2005), the average home spends $1,900 on energy costs per year. The total worth of Micro-Climate regulation in the region was found to be $6,412,500. The waste treatment provided by the natural resources of the region especially the Cascades, is helpful mostly because of the water it affects in Cook Pond and Coe's Reservoir. The most immediate effect of polluted water in Coe's Reservoir would be the lack of clean water to swim in. The replacement cost involved in installing a public swimming pool was measured to determine the total value for this service. Reviewing many estimates for both of the costs and comparing it to the value given by the department, the value of this service was determined to be $1.5 million initial cost and $53,520 per year which makes the thirty year total $3,105,600.

Soil based services were valued at $1,647,196.56. Soil is formed by decomposing organic matter into compost. The City of Worcester has a residential leaf collection program. A City Official estimates that the program collects approximately 75,000 to 100,000 pounds of leaves, which translates to 10,000 to 15,000 tons of compost per year. Assuming that the city has a uniform distribution of street tree cover (West Tatnuck constitutes 2.73%) and using estimates that compost cost $26 per ton (http://www.epa.gov/compost/basic.htm), this service will produce $7,103 per year and $213,090 over thirty. The naturally occurring cycle of nutrients through an ecosystem could be manually replaced by annual application of fertilizer. West Tatnuck, specifically, is rich in nitrogen and phosphorus; the chosen fertilizer must contain these elements. To re-nutrition an acre of land for these components would cost $65 to $90 (Fristoe & Gothard, 1998). There are 314 acres of land that would need to be fertilizer and over thirty years would cost $612,865.50. Erosion control is the cost to replace erosion resistant surfaces when development occurs. In order to determine this cost, the maximum number of new homes was determined from the build-out data from CMRPC. Only 5,000 sq ft of the 7,000 sq ft lot would require sodding. Using sod estimates from numerous sources (Lyons; Smith) a total sod cost of $2,422.54 per new home was assigned making the total value $821,241.06.

Figure 3: Individual Values and Category Comparison

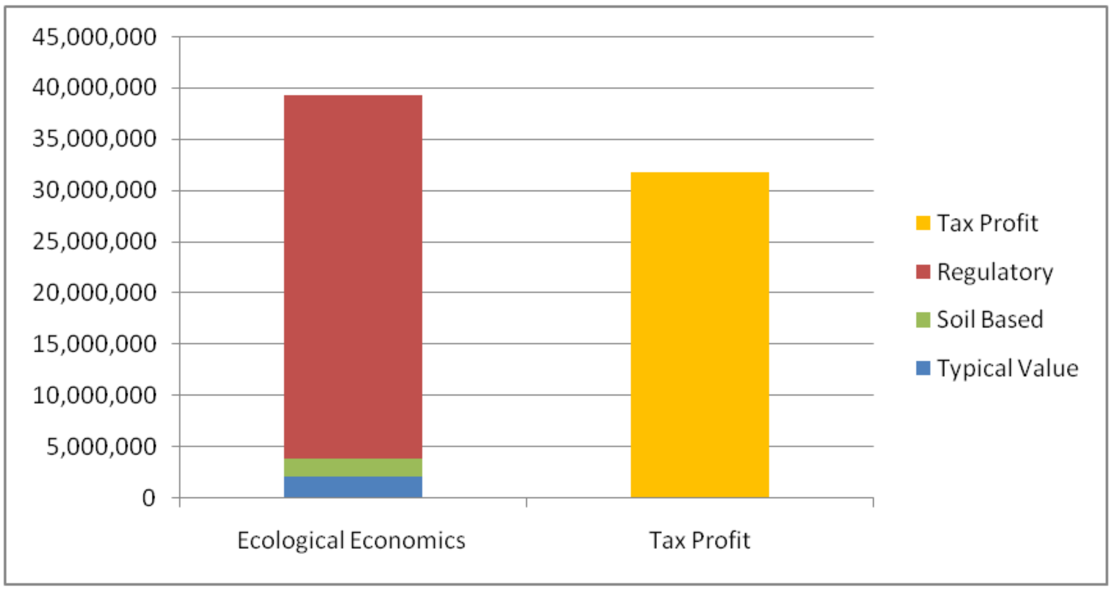
Ecological Service	Value ($/30 years)
Food Production	30,240
Raw Materials	379,129
Recreation	300,000
Cultural	1,461,750
Category Total	**2,171,119**
Noise Reduction	21,632,580
Air Filtration	2,008,650
Climate Regulation	6,412,500
Overland Flow Mitigation	2,250,000
Waste Management	3,105,600
Category Total	**35,409,330**
Soil Formation	213,090
Nutrient Cycling	612,900
Erosion Control	821,241
Category Total	**1,647,231**
Total	**39,227,680**



Discussion

Through a comparison of the calculated values (Figure 3) some inferences can be made. The traditional economic valuation a parcel of land would be considered profitable to develop if the potential tax yield from the region is greater than the typically economically valued factors. In the case of West Tatnuck, the maximum economic value of $31,782,773, if completely developed, would be much greater than the yield from timber, food products, recreation, and aesthetic value totaling $2,171,119. Because of this, development in the neighborhood would seem financially sound. However, in the more comprehensive valuation technique that this project proposed, the question of development gained another facet. Under this method, the value of all the ecological services of West Tatnuck (including those services traditionally accounted for in the economy) should be compared to the maximum economic value. In this case the open undeveloped space, valued at $39,227,678 outweighs the maximum economic value of $31,782,773 from development.

Figure 3: Value Comparison



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1: INTRODUCTION

Undeveloped land with intact ecosystems can provide a variety of benefits or “services” to adjacent or surrounding urban areas. For example, such a parcel might ameliorate the adverse effects of the urban development by reducing runoff and air pollution. Other benefits such as cultural, recreational, and aesthetic values may also be enhanced by maintaining such an undeveloped parcel within an urban area. These services are often adversely affected or even eliminated as a result of urban development. Since the development of a parcel is customarily assessed by calculating the profitability of such an effort and not the dollars associated with the loss of services, it is imperative to formulate a method that takes into account the value of services so that policy makers have complete information when determining cost-benefit analyses of development.

Currently, land is valued by the traditional economic valuation method, which assesses the maximum use value of the land. This value is based upon such factors as the cost to prepare the land for development, the number of houses that could be built within regulations, and the land’s proximity to public facilities (Fausold & Liliholm, 1996). In essence, it is based upon the potential to develop and does not reflect the current natural infrastructure. For example, the number of houses that can be built on a piece of land is factored into this value, but the ability of the ecosystem to replenish itself is not. The current economic system of valuation lacks the flexibility to account for the presence of ecological services, yet in building over them, the city incurs costs associated with replacing them by some means. Because of this it is necessary to formulate a more comprehensive method of valuation.

A true depiction of the value of a parcel of land would account for not only the market price of the land, but also the value of the services on it. Currently, there are three schools of thought with completely different methods of assessing value: traditional economic, ecological, and ecological economic (Costanza, 1997). The traditional economic and the ecological approaches are incomplete as they incompletely assess the relationship between human beings and the environment; the combination of these creates a third approach, ecological economics, which more completely accounts for this interaction. Previous research that has incorporated and ecological economic approach has focused mainly on valuing the ecological services on a larger, if not on a global scale. It was the goal of this project to refine this research and apply it at the local scale.

By analyzing a designated area of 676 acres in the West Tatnuck neighborhood of Worcester, Massachusetts this project assessed a specific value for the area, which includes a sizeable forest. This was achieved by examining West Tatnuck, comparing the difference between the traditional economic and ecological economic approaches, and using the latter to make the actual valuation. In previous research, generalizations had to be made because of the magnitude of the undertakings. This project avoided that pitfall. With the relatively narrow scope of this project the land can be examined to determine, more precisely, the services present. With these advantages, the project team was able to calculate the value of the ecological services of the study area accurately. This value can be a baseline to assess whether development would be cost effective, in the long run, to the City of Worcester by comparing it to the purely economic value of the West Tatnuck. Whether for the purpose of conservation or development, this project could be used as a framework by which to properly assess the true value of a given parcel of land.

2: BACKGROUND

The goal of this project was to determine the full value of the designated West Tatnuck area by assigning a monetary value to its ecological services. The following section contains the necessary background information needed to understand the intricacies of this project and what was needed to accomplish it. To provide an idea of the area, a description of West Tatnuck is included. This chapter will also examine the differences in valuation methods as well as possible provisions to safeguard ecological services for future generations.

VALUATION APPROACHES

There are three primary methods for the valuation of land which are detailed in Table 2.l. Ecology claims that all land has intrinsic value and thus, a monetary value cannot fully grasp the value of open spaces. Since the project focuses on monetary value of open spaces this approach is not explored further. On the other end of this spectrum is the conventional economy. Traditional economic approaches would value a parcel of land in a much different way if it takes

Table 2.1: Valuation Approaches

	Traditional Economic	***Conventional Ecological***	***Ecological Economic***
Ideological Emphasis	The Individual	The Environment	Interaction between Individual and Nature
Assumption About Technology	Expects to Improve	Ambivalent	Skeptical
Scope & Scale	Local to International, 50 yrs Maximum	Local to Regional, Variable Time Scale	Local to Global, Variable Time Scale
Goal	Growth of Economy, Profitability	Perpetuity of Ecosystems	Sustainability

into account the value of the services on it. This approach accepts technological advances as replacements to ecological services, while the other approaches take a cautious stance. Bockstael, Freeman, Kopp, Portney, and Smith (2000) state that economic value is based on the benefit to humans: “where human welfare is measured in terms of each individual’s own assessment of his or her own well-being” (p. 1385). The focus on the individual value is what separates this view from ecological economics. This approach can be seen as the marriage of traditional economics and a purely ecological standpoint. Ecological economics strives for sustainable development with the best interest of both the ecological services and the economy in mind. After defining the three approaches, the following sections will compare and contrast them.

TRADITIONAL ECONOMIC APPROACHES

The traditional economic approach focuses on the assumption that, "individual human consumers are the central figures [in the world view]" (Costanza, 1991, p. 4). Economists believe that the market and the stimulation of economic growth are the most important aspects in the environmental decision making process. Crocker and Linden (1998) support this, "Mainstream economists conceive (and approve) of consumption as the utilization of economic goods and services in the satisfaction of human wants" (p. 2). Thus their view on issues such as consumption is anthropocentric: the belief that the benefit of individuals (humans) is the primary concern in decision making. This view is not harmful as a general concept but the focus on individual value ignores benefits that are not easily assigned a monetary value through conventional means. Thus conventional economists generally believe that the environment is a subsystem of the economy and consequently serves little value in the economy besides a select few services, but not all. Traditional economic valuation methods claim that, "this is valuation by individuals according to their own preferences, through something that at least resembles a marketplace" (Pritchard, Folke, & Gunderson, 2000). Fausold and Liliholm (1996) further discuss this issue,

> "The most direct measure of the economic value of open space is its real estate market value; that is, the cash price that an informed and willing buyer pays an informed and willing seller in an open and competitive market. In rural areas where the highest and best use of land is as open space, this is easily determined by examining market transactions. In urban or urbanizing regions, however, where highest and best use (as determined by the market) is typically development, the open space value of land must be separated from its development value" (p. 1).

Therefore, the straightforward economic approach to assigning value land is to analyze a real estate value of the land, which overlooks many other aspects such as the value provided by ecological services on the land.

Also, economic perspectives see the environment as a "technical issue…This crisis will correspondingly be solved by the development and application of improved and new technologies, both to repair existing environmental damage and to prevent such damage occurring in the future" (Jacobs, 1991, p. 22). The economists stress that technological fixes can always replace the environment and should not be considered during development. Therefore, economy is not concerned with preservation of nature when considering development, since a basic premise is that the environment can always be fixed via man-made solutions later if at all necessary. This idea of the replacement cost of natural services focuses on technical fixes rather than the more comprehensive planning of development in order to preserve natural open spaces and prevent the need for the technological solution to the problems that arise with the elimination or hindrance of ecological services.

ECOLOGICAL ECONOMIC APPROACHES

Ecological economics has begun to develop methods that try to better account for the true value of all the ecological services provided by the earth. Costanza (1991) notes that, "*Ecological economics* is a new *transdisciplinary* field of study that addresses the relationships between ecosystems and economic systems in the broadest sense" (p.3). Costanza (1997) takes this approach by attempting to apply a price to the natural services the world supplies by tabulating the market value of the services present. This value is based on either, "(1) the sum of consumer and producer surplus; or (2) the net rent (or producer surplus); or (3) price times quantity as a proxy for the economic value of the service" (p. 257). Costanza cites the flaws of the economic and ecological extremes, because of this the ecological economic approach makes the most sense for land valuation.

The traditional ecological and economic viewpoints can be described as incomplete. Ecology places inherent value on land, rather than a quantifiable value. The ecological viewpoint can be discredited since humans cannot realistically be removed from the equation because an objective of this project was to gain a quantifiable monetary value. From the ecological viewpoint, development would never be feasible because nature would always have a higher value than what could be built. Since ecological services are not quantifiable in terms of individual benefits, traditional economy lacks the ability to account for them. In a market based economy, the value of services is derived from the willingness of the customer to pay for it. This is profitable for both parties because most services are excludable, that is, their benefits are controlled by and limited to the user. Ecological services are not excludable since they benefit the neighborhood as a whole and thus their full value is not realized on the market. However, since most policy and market decisions are based upon the economic perspective, it is worth exploring. Ecological economics attempts to blend its constituent disciplines. Costanza highlights this multifaceted feature as the strength of this field. It is that interaction that allows for a more complete method, as economy lacks the flexibility to account for ecological services.

TYPES OF VALUATION

This project utilized four different ways of assigning value to individual services. The first three valuation methods were derived largely from the work of de Groot, Wilson, and Boumans (2002). Under the concept of "indirect market valuation" they list avoided cost, replacement cost and hedonic pricing. Avoided cost is the amount the city does not have to spend because a natural system already provides a service whereas replacement cost is more specific to the installation and maintenance cost involved in setting up gray infrastructure to replace the work of the green infrastructure. For example, the decreased cost of health care due to cleaner air is an avoided cost, but the cost to build a water filtration facility is a replacement cost. Hedonic pricing is defined as "the prices people will pay for associated goods" (p. 403).

Table 2.2: Type Descriptions

Valuation Type	Application to Services	Example
Avoided Cost	Amount Saved in Lieu of	Cleaner Air Avoids Health Costs
Hedonic Pricing	Inherent Value	Increased Real Estate Value
Replacement Cost	Amount Spent to Replicate	Waste Facility Replaces Filtration
Willingness to Pay	Preferential Spending	Recreational Surveying

For the purpose of this project the effect open spaces have on the real estate value and consequently the revenue generated from property taxes of the surrounding houses was measured. Another method of valuing ecosystem services is "willingness to pay" which is defined by Bockstael et al. (2000) as "how much individuals would be willing to give up in other things to obtain this outcome" (p. 1387). This can be accomplished by doing surveys of the populace in the specific area or using results from older studies, but because of the subjectivity of this method, it is best saved for specific services such as recreation where other methods are insufficient.

ECOLOGICAL SERVICES

In West Tatnuck the benefits that the ecosystem provides can be characterized as ecological services. Dailey (1997) defines these services as the, ". . . conditions and processes through which natural ecosystems, and the species that make them up, sustain and fulfill human life" (p. 3). These services are performed by of all the aspects of ecosystems that provide benefits, either directly or indirectly, to a given population. More directly this means that, "ecosystem services are the actual life-support functions, such as cleansing, recycling, and renewal, and they confer many intangible aesthetic and cultural benefits as well" (p. 3). This concept has several distinctly different sides to it. Due to the intricacy of these services it was necessary to determine a list used for reference.

SERVICES ENUMERATED

There have been many attempts at identifying ecological services. Dailey (1997, p. 3-4) provides a basic list of ecological services (Table 2.3). Dailey's ideas were used by subsequent researchers and the identification process became finer and more appropriate for valuation. Although this list seems rudimentary it provides enough of an overview to gain at least a minimal understanding of the concept of ecological services and their function.

Table 2.3: Dailey's Ecosystem Services

- Purification of air and water
- Mitigation of floods and droughts
- Detoxification and decomposition of wastes
- Generation and renewal of soil and soil fertility
- Pollination of crops and nature vegetation
- Control of the vast majority of potential agricultural pests
- Dispersal of seeds and translocation of nutrients
- Maintenance of biodiversity, from which humanity has derived elements of its agricultural, medicinal, and industrial enterprise
- Protection from the sun's harmful ultraviolet rays
- Partial stabilization of diverse human cultures
- Providing of aesthetic beauty and intellectual stimulation that lift the human spirit

Costanza (1997) reinterprets Dailey's list and identifies seventeen distinct categories of ecological services (Table 2.4) based on an assessment of eleven different biomes[1]. This list of services is more refined and thus helps to simplify the identification process. The relationship between these ecosystem functions and services are quite complex. As Costanza (1997, p. 253) notes:

> ". . . ecosystem services and functions do not necessarily show a one-to-one correspondence. In some cases a single ecosystem service is the product of two or more ecosystem functions whereas in other cases a single ecosystem function contributes to two or more ecosystem services. It is also important to emphasize the interdependent nature of many ecosystem functions."

Different functions can perform part of more than one type of services. For example, the ecosystem *function* of nutrient cycling provides the service of fertilizing the soil and regulating pollution related to nitrous gases. Consequently, gas regulation is a service that requires the function of air filtration and nutrient cycling. The importance of balance presents a pressure to ensure that the integrity of intact systems, rather than the preservation of individual services, is upheld. The work performed by Costanza spoke in a global context, as it analyzed the ecological

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[1] Open Ocean, Coastal, Forest, Grass/Rangelands, Wetlands, Lakes/Rivers, Desert, Tundra, Ice/Rock, Cropland, and Urban (Costanza, 1997, p. 256)

Table 2.4: Costanza's Ecological Services (1997, p. 254)

Table 1 Ecosystem services and functions used in this study

Number	Ecosystem service*	Ecosystem functions	Examples
1	Gas regulation	Regulation of atmospheric chemical composition.	CO_2/O_2 balance, O_3 for UVB protection, and SO_x levels.
2	Climate regulation	Regulation of global temperature, precipitation, and other biologically mediated climatic processes at global or local levels.	Greenhouse gas regulation, DMS production affecting cloud formation.
3	Disturbance regulation	Capacitance, damping and integrity of ecosystem response to environmental fluctuations.	Storm protection, flood control, drought recovery and other aspects of habitat response to environmental variability mainly controlled by vegetation structure.
4	Water regulation	Regulation of hydrological flows.	Provisioning of water for agricultural (such as irrigation) or industrial (such as milling) processes or transportation.
5	Water supply	Storage and retention of water.	Provisioning of water by watersheds, reservoirs and aquifers.
6	Erosion control and sediment retention	Retention of soil within an ecosystem.	Prevention of loss of soil by wind, runoff, or other removal processes, storage of stilt in lakes and wetlands.
7	Soil formation	Soil formation processes.	Weathering of rock and the accumulation of organic material.
8	Nutrient cycling	Storage, internal cycling, processing and acquisition of nutrients.	Nitrogen fixation, N, P and other elemental or nutrient cycles.
9	Waste treatment	Recovery of mobile nutrients and removal or breakdown of excess or xenic nutrients and compounds.	Waste treatment, pollution control, detoxification.
10	Pollination	Movement of floral gametes.	Provisioning of pollinators for the reproduction of plant populations.
11	Biological control	Trophic-dynamic regulations of populations.	Keystone predator control of prey species, reduction of herbivory by top predators.
12	Refugia	Habitat for resident and transient populations.	Nurseries, habitat for migratory species, regional habitats for locally harvested species, or overwintering grounds.
13	Food production	That portion of gross primary production extractable as food.	Production of fish, game, crops, nuts, fruits by hunting, gathering, subsistence farming or fishing.
14	Raw materials	That portion of gross primary production extractable as raw materials.	The production of lumber, fuel or fodder.
15	Genetic resources	Sources of unique biological materials and products.	Medicine, products for materials science, genes for resistance to plant pathogens and crop pests, ornamental species (pets and horticultural varieties of plants).
16	Recreation	Providing opportunities for recreational activities.	Eco-tourism, sport fishing, and other outdoor recreational activities.
17	Cultural	Providing opportunities for non-commercial uses.	Aesthetic, artistic, educational, spiritual, and/or scientific values of ecosystems.

* We include ecosystem 'goods' along with ecosystem services.

services of the world. For application to this project, the scope of his work must be narrowed to account for the more specific role of ecological services near urban areas.

ECOLOGICAL SERVICES IN URBAN AREAS

The description Costanza provides for ecological services is still applicable to urban areas with minor adjustment. Bolund and Hunhammar (1999) identified six of their own services

(Table 2.5) that were adapted from Costanza's seventeen ecological services that are more appropriate for urban areas. These adaptations are outlined in Table 2.5. Changes include the reduction of climate regulation to microclimate regulation and the definition of waste treatment as sewage treatment. The service that Costanza defines as disturbance regulation is divided by Bolund and Hunhammar, as it takes on two drastically different functions (noise reduction and rainwater drainage) in an urban environment.

Table 2.5: Urban Ecological Services

Costanza Services		Bolund & Hunhammar Services
Gas Regulation	√	Air Filtration
Climate Regulation	√	Microclimate Regulation
Disturbance Regulation	√	Noise Reduction, Rainwater Drainage
Water Regulation		
Water Supply		
Erosion Control		
Soil Formation		
Nutrient Cycling		
Waste Treatment	√	Sewage Treatment
Pollination		
Biological Control		
Refugia		
Food Production		
Raw Materials		
Genetic Resources		
Recreation	√	Recreation/Cultural Value
Cultural	√	

In a case study of Stockholm, Sweden, Bolund and Hunhammar (1999) classify seven different ecosystems: "street trees, lawns/parks, urban forests, cultivated land, wetlands, lakes/sea, and streams" (p. 294). Of these ecosystems, West Tatnuck would best be categorized as an urban forest containing a stream. Bolund and Hunhammar chose to ignore Costanza's categories of food production, erosion control, and waste water treatment as they are relatively unimportant in the Stockholm situation. A similar approach of adapting Costanza's services to West Tatnuck was used by this project.

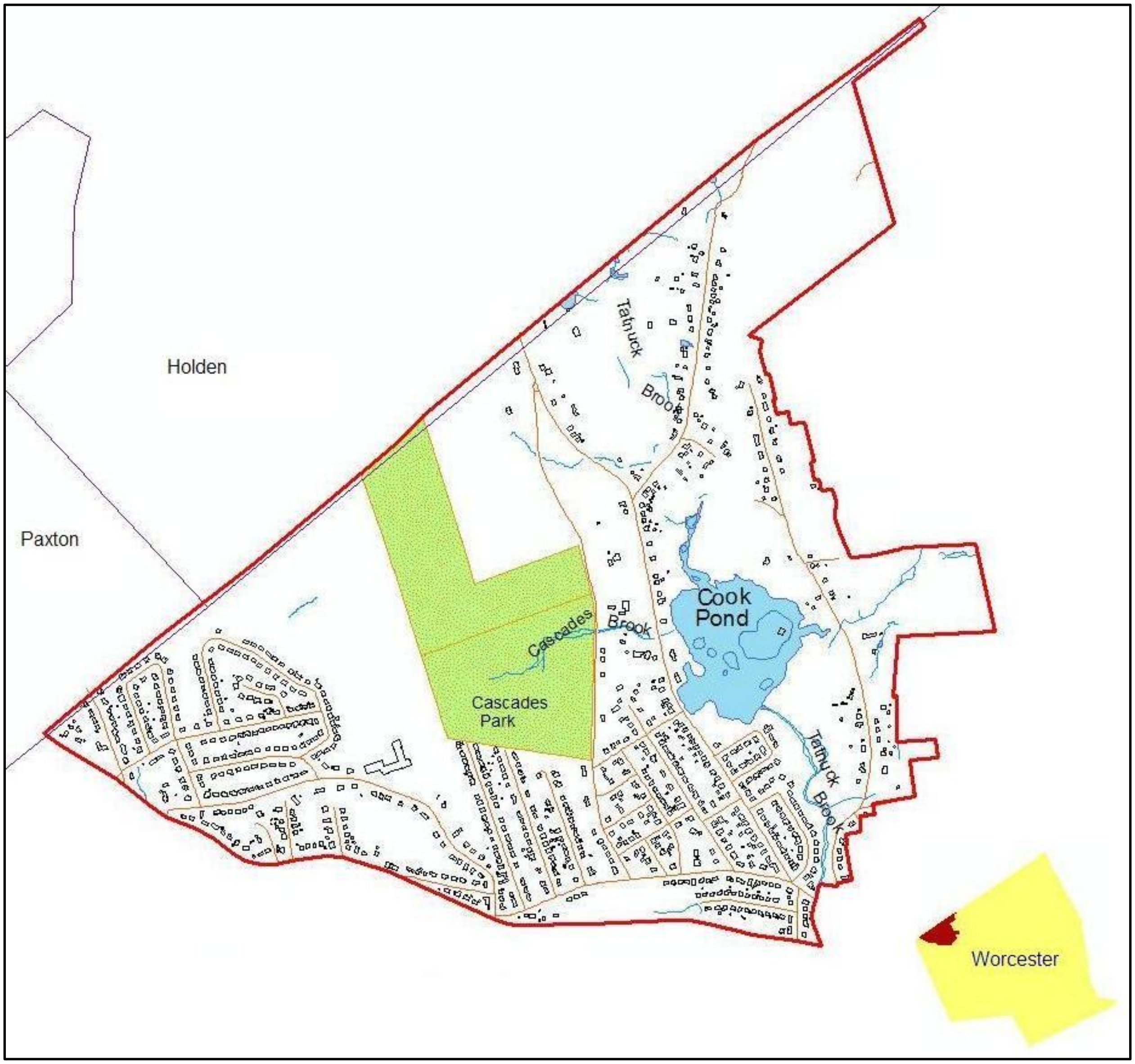
Ecological services, especially those in close proximity to urban areas, provide valuable benefits to the community. Currently, there is no mechanism to value these services in the traditional economy; because of this the proposed valuation methods are contested. For this project it was necessary to discuss the differences between the traditional economic approach and the ecological economic approach and determine which to apply. The Worcester planning board must base land use planning decisions in urban forests on what is most profitable for the city after accounting for the value of ecological services in them. If ecological services are to be protected, the planner has several tools at her disposal and thus the next section focuses on both the conventional and the newly developed tools for the purpose.

WEST TATNUCK

West Tatnuck is a residential neighborhood in Worcester, Massachusetts and one of the more forested in the municipality. The study area defined in Figure 2.1 is an approximation of West Tatnuck, as no official boundary exists except the Worcester city limit caps the region from the southwest to the northeast. The southern edge is bounded by MA Route-122 and Pleasant Street. The rest of the boundary was defined by the all the parcels on the east side of Tory Fort Lane. The West Tatnuck region is mainly an urban forest with single family homes on the periphery and some commercial development along Pleasant Street in the south. The forest is a mix of deciduous and evergreen trees with a stream running through it. This stream runs through the area known as the Cascades into another region that is named Cascading Waters and eventually drains into Cook’s Pond. Coe’s Reservoir is a few miles south of the Cascades and downstream from Cook's Pond. West Tatnuck contains approximately 457 acres of land with 300 acres (66 per cent) consisting of the Cascades Park. This land is preserved by the Greater Worcester Land Trust for recreational purposes.

Worcester became a town in 1722 and was incorporated into the Commonwealth as a city in 1848. While Worcester itself became a hub of the American Industrial Revolution, West Tatnuck remained largely agricultural and had a negative attitude towards development. The region had only four roads for some time and was comprised mostly of farmland. After industrialization, as downtown Worcester sprawled outward, the once isolated farming community became increasingly connected to the city. The farmland was subdivided to form residential areas, as well as small pockets of commercial space. Since it was settled, West

Figure 2.1: Map of West Tatnuck with Worcester Insert



Tatnuck has been one of the more rustic areas of Worcester, and with its previous and current attitudes towards development, it will remain that way for some time.

3: METHODOLOGY

The goal of this project was to adapt existing valuation methods in order to apply them at a local level to natural open spaces, by accounting for the value of their ecological services as current methods have been deemed incomplete. The first step in the valuation process was to determine the strict economic value of the region for comparison to the ecological economic section. Before the ecological economic value is determined, it was necessary to identify the ecological services present in the West Tatnuck. Then methods for measuring and approximating the value of these services were established. The difference between this value and the traditional economic value highlights the comprehensive nature of ecological economics.

ECONOMIC VALUATION

To determine the maximum economic value of West Tatnuck, the project obtained build-out analysis from the Central Massachusetts Regional Planning Commission (CMRPC). This analysis yielded data that determined the maximum number of structures that can be built on parcels of unprotected open space in Worcester. Protected open space makes up a significant portion of the study area. This presents a limitation, as the build-out analysis does not account for a sizeable portion of West Tatnuck and this could lead to skewed data. Therefore, a protected open space build-out projection was created by the project team using the zoned RS-7 minimum lot size of 7,000 square feet and the total square footage of protected open space parcels not falling in the FEMA flood plain. This build-out projection was added to the CMRPC build-out data to determine the maximum build-out of West Tatnuck including development of protected open spaces. Using the average assessed value of houses in the area obtained from the Worcester City Assessor, the economic total land value of West Tatnuck was calculated by multiplying this figure by the maximum number of homes that could be constructed. This total will be applied to a thirty year period, which is the length of a typical deed.

The tax revenue from these homes provides income for the City of Worcester. Therefore, the total worth of all of the homes based on the previous calculation was multiplied by the Worcester tax rate, which was acquired from the city assessor, to determine the tax value of the land. This is the maximum economic value that West Tatnuck could provide to

Worcester. However, education costs pose one of the largest expenditures for the city. By adding residential units to West Tatnuck through build-out analysis, additional school age children will be introduced to the school system.

To determine the portion of the tax revenue allocated from these addition single family homes, the number of new students brought into the school district was determined and the cost for one year of public education was also necessary. The cost for public education per child for one year was obtained from numerous sources. After analyzing the cost of K-12 schooling for these children, the financial burden for education was calculated for new housing units in West Tatnuck, representing a decrease in the economic value of the area. The introduction of a substantial number of new students into the local school system also creates a need for more educational infrastructure in the form of a new school. The cost of this was investigated. By subtracting these education costs from the maximum tax revenue of the area, an approximation of the total economic value of development of the study area can be assessed. However, this value is fails to account for gray infrastructure costs. Thus it is higher than the actual economic profit that the city of Worcester could take in. The newly developed parcels would need to be equipped with adequate public facilities before development can occur. Regardless, this number provides an absolute maximum economic value for further comparison.

IDENTIFICATION OF ECOLOGICAL SERVICES

To appropriately value West Tatnuck it was necessary to determine a specific list of the services present within it. The seventeen categories of services Costanza (1997) provides (Table 2.4) encompass *all* the world's ecosystems. Thus, some of these services will not apply to West Tatnuck or even forests in general. For the most part, the availability and prevalence of individual services in the area were the criteria upon which services were added to the final list. To a lesser extent, the scope of this project was taken into account during the final identification. Table 3.1 provides a list of the ecological services, why each is included/excluded, and the valuation techniques this project will adopt to quantify the ecological services in West Tatnuck.

Table 3.1 Elimination and Valuation

Ecological Services	*Use?*	*Reason to Include/Exclude*	*Valuation Techniques*
Gas Regulation	√	Sufficient Tree Cover	Governing Equation
Climate Regulation	√	Creates Microclimate	Cost to Heat/Cool Home
Disturbance Regulation	√	Hinders Flow; Reduces Noise	Cost of Driveway Swales/ House Value Deficit Near Airport
Water Regulation		Not Allocated to Specific Use	
Water Supply		Not Provisioned for Drinking	
Erosion Control	√	Becoming a Problem in Area	Cost to Sod Additional Lawns
Soil Formation	√	Fallen Leaves Create Soil	Value of Soil Gained by City Compost
Nutrient Cycling	√	Cycle is Active in the Region	Cost to Re-Nutrition Soil
Waste Treatment	√	Bathing Beaches Downstream	Cost to Replace Beaches with Municipal Pools
Pollination		Eliminated Due to Scope	
Biological Control		Eliminated Due to Scope	
Refugia		Eliminated Due to Scope	
Food Production	√	Sap from Sugar Maples	Value of Syrup Gained from Sugar Maples
Raw Materials	√	Sustainable Tree Harvest	Value of Timber That Can be Sustainably Harvested
Genetic Resources		Not a Viable Source	
Recreation	√	Hiking, Fishing, Biking	Willingness to Pay for Passive Recreation
Cultural	√	Aesthetic Value	Increase in Price of Houses in Aesthetically Pleasant Areas

Services Not Present

Of the list of the original seventeen ecological services, three can be eliminated because they are not present in West Tatnuck. The Tatnuck Brook is not directly allocated to specific uses (agriculture, industry, drinking supply, etc.), so the water based ecological services can be eliminated. Also, there are no known desirable genetic traits in the flora or fauna of West Tatnuck, so their genes are not being harvested for scientific use. After modifying the list for relevance to the area, it was also necessary to refine the list based on the limitations of this project.

Outside the Project's Scope

The scope of this project does not allow for long term observation, such as the tracking of fauna populations. As listed in Table 3.1, pollination, biological control, and refugia are outside the scope of this project as they involve such surveillance. To calculate these services the population and density of honey bees, keystone predators, and transient species would need to be tracked for multiple years to properly assess the corresponding services, and such data has yet to be recorded. The duration of the research period of this project, narrows the ability to track these populations.

Examined Services

After eliminating the services previously mentioned, eleven[2] ecological services exist in West Tatnuck that are within the scope of this project. Based on Bolund and Hunhammar the list can be modified in terminology to better match the particular circumstances of an urban forest. Costanza's service of disturbance regulation can be divided into overland flow mitigation and noise reduction. Both of which can be equated to, "other aspects of habitat response. . ." (Table 2.4). As a further simplification, the cultural service can be equated to an aesthetic one, as West Tatnuck does not provide spiritual or scientific value. After taking these changes into account the list of the ecological services in the region will be fixed at twelve.

[2] Gas Regulation, Climate Regulation, Disturbance Regulation, Erosion Control and Sediment Retention, Soil Formation, Nutrient Cycling, Waste Treatment, Food Production, Raw Materials, Recreation, and Cultural

Service Categorization

To simplify the discussion of these services they were divided into three categories, as referred to in Table 3.2. The services that deal with the control of phenomena were grouped into the regulatory category that is defined by the first column of the table. Erosion control, soil formation, and nutrient cycling were grouped together as they all are soil based ecological services and are interrelated. The remaining services, listed in the third column of Table 3.2, are traditionally taken into account by the economy and their values are defined thusly.

Table 3.2: Service Classification

Examined			Unexamined	
Regulatory	***Soil Based***	***Economic***	***Not Present***	***Outside Scope***
Air Filtration	Erosion Control	Aesthetics	Genetic Resource	Biological Control
Climate Regulation	Nutrient Cycling	Food Production	Water Regulation	Pollination
Noise Reduction	Soil Formation	Raw Materials	Water Supply	Refugia
OLF Mitigation	-	Recreation	-	-
Waste Treatment	-	-	-	-

Valuation Techniques

The next objective was to ascertain values for the services that were identified as present in West Tatnuck and within the scope of this project. The values of services that are typically included in economic valuation were included in the ecological economic value, as they make up a portion of this figure. The regulatory and soil based services required more abstract valuation methods to determine an accurate value, as outlined in Table 3.1. The techniques for each valuation were determined after an in-depth literature review. These values could be a one-time price, a yearly cost, or both. The following are the means by which these values where determined as well as any necessary measurement techniques that were needed.

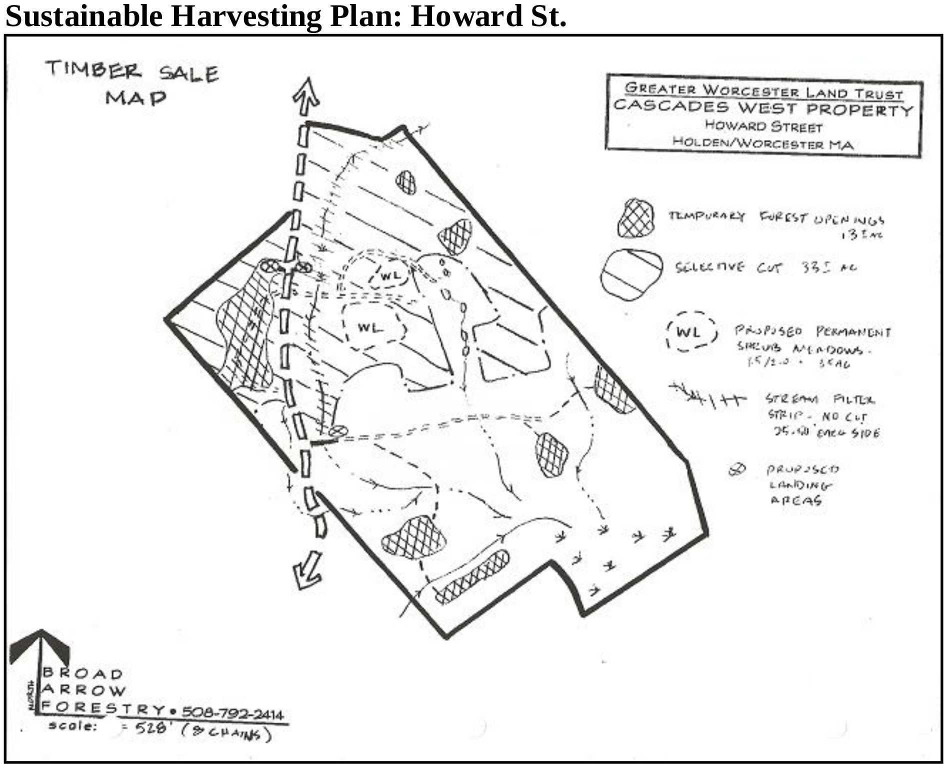
Economically Valued Services

Traditional economic valuation techniques exist for some of the ecological services that are present in West Tatnuck. These services include food production, raw materials, recreation, and aesthetics. Though these are economically valued using existing methods, they will still be included in this accounting as they are ecological services that exist in West Tatnuck.

The most readily quantifiable source of food in West Tatnuck is maple sap. The potential for food to be produced from the region has not yet been realized, as none of the trees are currently tapped. Sap can be processed into several consumer goods, and also can be sold as a raw good. The number of sugar maple trees in the study area was determined using tree surveys conducted by Bertin (1999, 2000) in Worcester. The project team evaluated five regions that border the region to determine the average number of trees per acre. This was multiplied by the number of loosely forested acres (per Bertin's tree surveys and GIS[3]) within the study area, as sugar maples do not grow in dense forest. After obtaining the number of trees, the average amount of sap produced per tree was determine by consulting local sap harvesters. The sap produced by the trees in the study area was valued based on the market price to potential value of food produced in West Tatnuck. This value can be accrued yearly and thus would be part of a long-term comparison to the build-out scenario and the maximum economic value.

Raw materials usually make up the majority of the value for a parcel of land. The only substantially harvestable material in the area is timber. Through the process of sustainable foresting, careful harvesting of timber can be allowed for minimal impacts on the forest and

Figure 3.1: Sustainable Harvesting Plan: Howard St.



[3] Geographic Information System. The software used was ArcView GIS.

ample regeneration of trees to maintain a balanced ecosystem. Careful planning is taken to ensure this balance by in-depth plans (Figure 3.1). To value this service, the number of trees that can be sustainably removed from West Tatnuck was determined. The tree data provided by Bertin (1999, 2000) and the GIS software combined with the foresting data from Broad Arrow Forestry helped to determine the type and the amount of timber that can be harvested. Timber (measured in cords or board feet) can be valued by its market price. This service could be a one-time cost if the region is clear-cut or a yearly value if sustainable harvesting is adopted. This value may change from year to year; however, over relatively short spans, it will not change.

Recreation is harder to value as most of the activities in West Tatnuck are free to the public. To calculate willingness to pay for recreation, various forms of passive recreation were analyzed in West Tatnuck, including hiking, picnicking, fishing, hunting, and general recreation purposes. The average willingness to pay for these services was researched from several park and forest studies such as the U.S. Forest Service's recreation values. The total number of passive recreation participants in West Tatnuck was obtained from the Greater Worcester Land Trust. Based on the total number of recreational visits to park and open space land in West Tatnuck and the average willingness to pay per person, a total recreation value per year was obtained for West Tatnuck.

Urban forests, streams, and ponds provide an aesthetic value, such as the Cascades, Tatnuck Brook, and Cook's Pond. In order to evaluate this ecological service, we looked into real estate values in the area by contacting realtors and analyzing assessor's data. We determined how much higher a property is valued based on this aesthetic value and how many homes abut these aesthetically pleasing sites by contacting a local realtor. This concept is known as Hedonic Pricing. By applying this increase to all of the houses in question the aesthetic value of West Tatnuck can be determined. Though this value only tangibly presents itself in the sale of a house, the benefit can be considered a long-term value as it continues to be present and can change with time.

REGULATORY SERVICES

Services that check and balance natural phenomena provide some of the more tangible ecological services. This category includes air filtration, microclimate regulation, noise reduction, overland flow mitigation, and waste treatment. These can be measured by avoided or replacement costs to recreate the function of the services.

Air filtration contributes to the removal from the air of greenhouse gases and other pollutants such as Carbon Monoxide (CO), Ozone (O_3), Nitrogen Dioxide (NO_2), Sulfur Dioxide (SO_2), and Carbon Dioxide (CO_2). In order to measure this service, the amount of tree cover in West Tatnuck determined by Google Maps™ and GIS, along with tree surveys performed by Bertin was used to determine forested areas. The worth of filtering certain quantities of each type of gas was calculated using CITYgreen software. Filtration is valued by the model:

Equation 3.1 Air Filtration Measurement

$$F\ (g/cm^2/sec) = V_d\ (cm/sec) \times C\ (g/cm^3)$$

Where (F) is the pollutant removal rate, (V_d) is the deposition velocity, and (C) represents the pollution concentration. Using other CITYgreen estimates the amount of carbon sequestration was determined by scaling data from other cities to West Tatnuck. Using these figures, the total amount of air filtration in West Tatnuck and the corresponding value were calculated. The yearly amounts of pollutants filtered out of the air should be considered in long-term comparisons as this service can only get more valuable as time goes on.

Micro-climate regulation is reduction of temperature, solar radiation, and wind speed in areas due to tree cover, bodies of water, and fewer heat absorbing surfaces. According to a study by the EPA (2007), “U.S. cities and suburbs have air temperatures up to 10°F (5.6°C) warmer than the surrounding natural land cover.” This phenomenon, known as the “heat island effect”, is caused by a lack of green infrastructure combined with a greater absorption of heat by roads and a higher energy usage in downtown urban areas. In winter, forests reduce wind speeds; houses that are exposed to higher speeds need to spend more annually on heating (Bolund & Hunhammar 1999, p. 296). Thus, micro-climate regulation is effective year round. The areas near the Cascades benefit from a slightly milder weather than their urban counterparts. The difference between energy usage in downtown Worcester and in West Tatnuck from heating/cooling was used to assign a monetary value for this service during summer by using a mathematical model provided by the Massachusetts Institute of Technology. This value is compounded annually to determine a long-term value for comparison to urban counterparts.

Overland flow is mitigated through absorption by natural surfaces such as soil or grass. When such permeable surfaces are replaced with non-permeable ones as a result of development, the increased volume of the flow has the possibility of being harmful. Santoyo (2007) affirms this point:

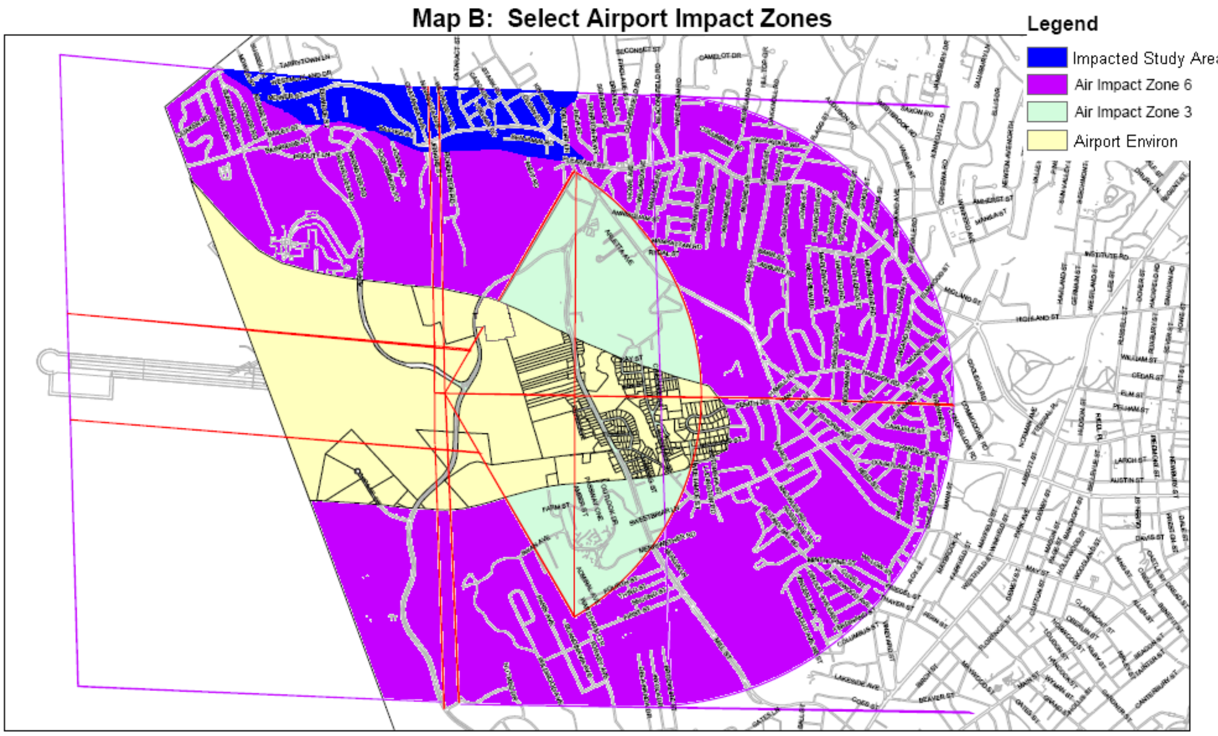
> "Water runoff is predictably accelerated by human activity. With the clearing of natural vegetation comes the addition of impermeable surfaces (roofs, roads, concrete, and other "hard" surfaces). Without the landscape's natural surface, water can no longer soak into the soil; accelerated stream flow, flooding and erosion results."

Massachusetts Stormwater Management Policy from the Department of Environmental Protect (1997) requires that the flow through a parcel of land before development be equal to or less than post development. The permeable surfaces of the study area, especially the forest floors, effectively absorb a lot of the overland flow. If the green infrastructure did not exist, there would be a much larger volume that would need to be mitigated. The avoided cost to the individual owner of installing infrastructure to absorb water was used to value this service.

With its undeveloped spaces and natural filtering services, West Tatnuck removes pollutants from groundwater and runoff. This water flows through West Tatnuck and eventually makes its way to Coe's reservoir. While this water is not used for drinking, its quality is important because there are public beaches on the reservoir. To gauge the value of this ecological service, the replacement costs associated with installing and maintaining a public pool was determined in the case that these beaches were no longer clean enough for swimming. The initial cost and the maintenance cost per year were found by contacting the Worcester Parks and Recreation Department. The installation cost can be used in short-term discussions while maintenance can be analyzed in the long-run.

The only substantial noise to reduce is from the airplanes that fly over the region. To determine if there is significant enough noise to be reduced, the total number of flights in and out of the airport was found. There are sufficient houses in this area affected by flight noise (shaded blue in Figure 3.1) to warrant valuing this service. These houses fall into Airport Impact Zone Six, or the Traffic Pattern Zone. This zone allows for low density development,

Figure 3.1: Flight Impact Zones in West Tatnuck



accommodating less than 100 people per acre (FAA, 2005, p. V-38) Using the above-mentioned Hedonic Pricing Model in reverse and the report published by Nelson (2003) the price deficit of homes can be estimated. Similar to aesthetic value this deficit is only accounted for during property transactions, though it can be considered a negative value over time.

Soil Based Services

Soil based services are integral to ecosystems as they can have significant impacts on the functionality of other services. The services in this category are: Soil Formation, Nutrient Cycling, and Erosion Control. These contribute to not only the health and sustainability of an ecosystem, but also the physical structure of an area. Soil based services contribute to the wellness of the terrain as well as the balance on the environment as a whole.

Soil is formed by the decomposition of organic matter. For West Tatnuck, the foliage in autumn provides most of the topsoil for the coming years. To measure the amount of soil formed in the region, the amount of leaves collected by the city from the residential buildings during fall was investigated. By contacting the Worcester Department of Public Works the estimate amount of compost produced per year was determined. To assign a value to this the wholesale price of compost was applied to the total amount of compost produced per year.

The nutrients in soil are huge factors in determining the health of the plants and the efficiency of the ecological services that could be provided to human beings. Nitrogen (N), sulfur (S), and Phosphate (P) are the most important elements to the growth of organisms. The growth of plants is limited by these elements, macro-nutrients (calcium, magnesium, potassium, sodium, and chlorine), trace elements (iron and zinc), atmospheric changes, weathering of rock material, and fertilizer application (de Groot et al., 2002). Without proper nitrogen fixation, the soil would have to be fertilized in order for plants to grow to their full extent. One of the ways to measure the effectiveness of nitrogen fixation by a forest is to determine the amount of fertilizer that would have to be used to provide similar nutrition. The price of the fertilizers can then be assigned as a value to this ecological service per year over time.

Erosion is the loss of soil, sediment, and rock fragments by various agents. To effectively control erosion is to minimize or negate the effect that external forces have on the system. Large amounts of siltation into the water system could potentially “choke” and damage the ecosystems. The value of this was determined by the cost incurred with new development to prevent soil erosion of the remaining 5,000 square feet of a 7,000 square foot lot. This is accomplished by evaluating the cost of purchasing and installing sod over this area to keep soil and sediment in place.

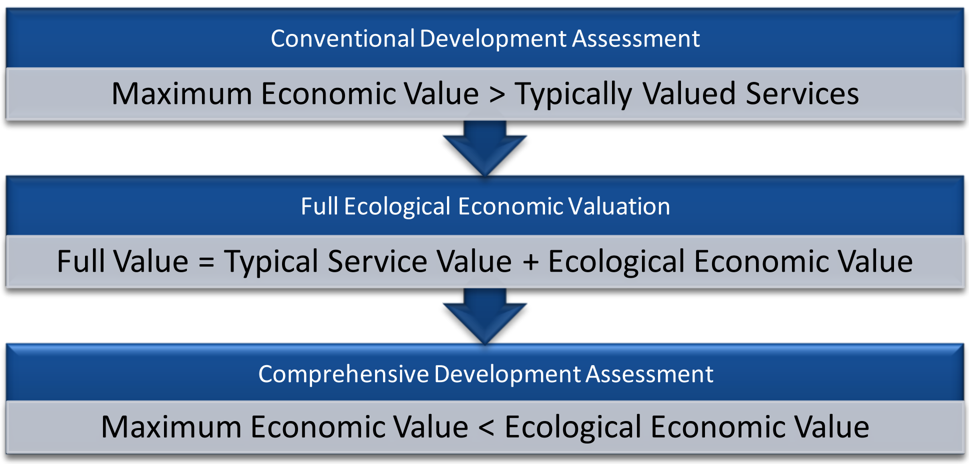
SUMMARY

This project was performed in three basic steps: the identification of services, the measurement thereof, and assessing a value based on that measurement. The first of these was achieved by a series of logical eliminations for reasons of scope and availability. Next, the remaining services were given rudimentary quantification techniques for proper measurement. After this, valuation analogs were created to apply a rough approximation of value. This was compared to a defined economic value to display the more complete nature of ecological economic approach.

4: FINDINGS

Within traditional economic valuation a parcel of land would be considered profitable to develop if the potential tax yield from the region is greater than the typically economically valued factors. Figure 4.1 outlines the progression of findings specific to West Tatnuck. In this case, the maximum economic value, if completely developed, would be much greater than the yield from timber, food products, recreation, and aesthetic value. Because of this, development in West Tatnuck would seem financially sound.

Figure 4.1: Findings for West Tatnuck



However, this project proposed a more comprehensive approach to the typical valuation techniques. The full value of West Tatnuck was calculated by valuing all ecological services (including those already accounted for in the economy) which was greater than the maximum economic value. This finding can make a case against development.

CONVENTIONAL DEVELOPMENT CONSIDERATION

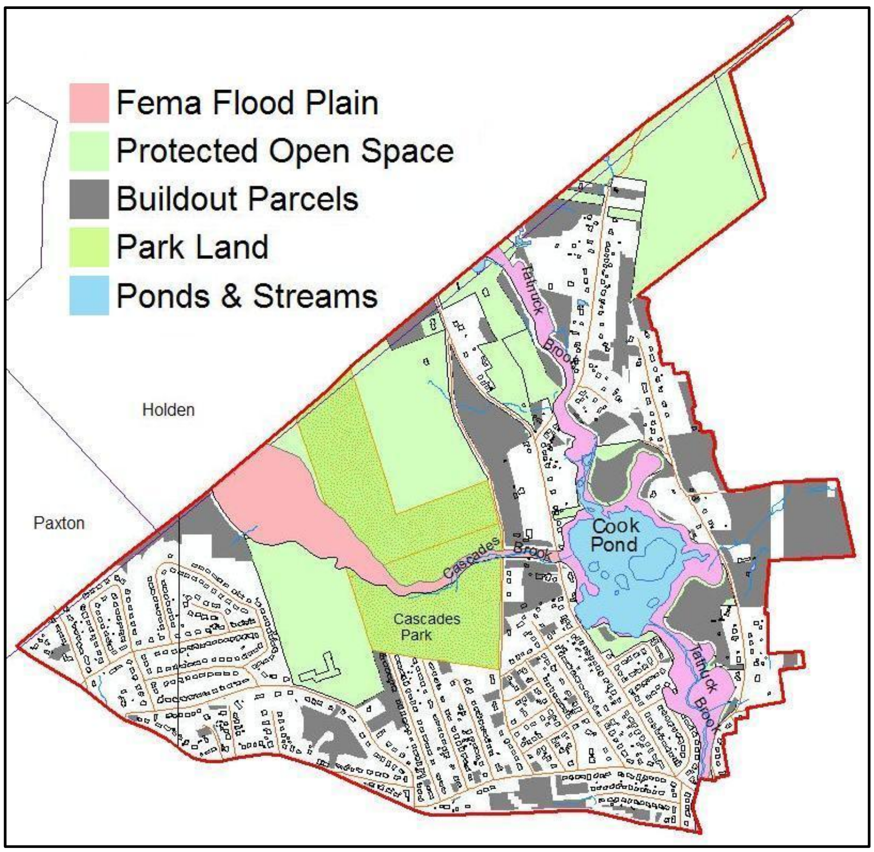
In conventional land use planning, development is considered lucrative enough to be implemented if the maximum economic value exceeds the value of opportunity costs. In this case, there are four factors in the traditional economy that would keep land from being developed if they are more profitable than the generated tax revenue in the region. The maximum tax revenue from West Tatnuck outweighs that of the services in it that are valued by the economy.

Because of this, typical valuation would deem West Tatnuck as a financially feasible region for further development.

MAXIMUM ECONOMIC VALUE

The Central Massachusetts Regional Planning Commission (CMRPC) estimates that 339 additional units could be built in West Tatnuck if needed (Figure 4.2). Based on the open space build-out projection done by the project group, 1026 additional units could be built on protected open space if these conservation restrictions were not in place. The projection divided all open space into 7,000 sq ft parcels, excluding the FEMA flood plain[4] (highlighted in pink in Figure 4.2). This places the maximum number of new homes that could be built in West Tatnuck at 1,365 RS-7 units. These houses would generate revenue in the form of property tax for the city. Because the new-built houses will be on 7,000 square foot lots, they will likely be smaller than the average home in West Tatnuck, but because they are newer they will be worth more.

Figure 4.2: Build-Out Map



[4] The FEMA flood plain cannot be developed without taking costly precautions, so it will not be developed in the project team's analysis.

Because of this, the price of the new houses can be equated to average of the existing houses, which is approximately $183,000[5]. At Worcester's current tax rate of 1.21%, over thirty years the additional units in the region would generate another $90,694,830 of gross profit for the city.

The Worcester build-out analysis projected 4,620 new school age children, or an average of 0.42 school age children per new home. Based on the 1,365 new single family residential units 573 new school age children would be introduced to the school system in the study area. Assuming an average distribution of these students throughout the K-12 system, the city would have to pay for 5,577 total years of schooling for the original 573 students. The cost per year of public education for a single student is $7362.75[6]. Therefore Worcester would incur a $41,062,057 cost for educating students from these new homes. However, this educational cost over the 30 year period does not account for the potential need for additional school infrastructure to handle these students and the younger children brought into West Tatnuck or births which will add more school age children to replace those who graduate out of the original 573 students. In order to handle these additional 573 students in the local school system, Worcester would have to build at least one new school in the district. It would cost the city around $17,850,000[7] to add an adequate school facility to accommodate such an increase in the number of students. This reduces the profit from the study area's tax revenue to $31,782,773.

TYPICALLY VALUED SERVICES

The conventional method of determining when development is *not* feasible takes into account the value of the goods (food products, raw materials) and services (recreation, aesthetics) that can be marketed to the general public. Thus, if they are found to be more profitable than the tax revenue, allowing a parcel to stand would be best for the city.

The sap production in West Tatnuck is provided by approximately 504 sugar maples of adequate size in the region. The average sugar maple tree can produce ten gallons of sap in one season at a value of $0.20 per gallon, as provided by a local expert in syrup harvesting. These

[5] Average from City Assessor
[6] Average based on National Education Association (2007), Joint Economic Committee (1997), Levine (2007)
[7] Average based on Citizens for Public Schools (2007), North Carolina Prototype School Design Clearing House (2007), Vaznis (2007) and Whitson (2007)

trees can be tapped for sap yearly at a value of $2.00 per tree. Over thirty years the region could produce $30,240 of raw sap, which could then be sent off to be processed into finished maple products.

Through a regiment of sustainable harvesting the timber in West Tatnuck could realistically be cut three times in thirty years. According to Broad Arrow Forestry harvesting plans, a combined 104.5 acres of the region has sustainability practices in place (Plourde, 2007). These three regions yielded 34.5 mega-board feet (mbf) and 181 cords of wood. Per acre this would be equivalent to 0.33 mbf and 1.73 cords to be harvested. The value of wood sold by the mega-board foot (larger trees for commercial use) is $170 per unit; this is based on an average of the species available in the region (University of Connecticut Forestry Department). Cords are sold for firewood and other applications. The price of this is determined in part, by proximity to the source and according to University of Massachusetts Amherst, the market price of the wood itself, the average of which is $200 per cord (Forestry Department, 2006). By extrapolating this into West Tatnuck, the 314 harvestable acres could yield $126,376.40 per harvest and $379,129.20 over thirty years.

There are multiple forms of recreation in West Tatnuck. The Greater Worcester Land Trust estimates that 2,500 people participate in passive recreation over the course of a year. For these activities, the average individual is willing to pay $4 per person per visit. This figure was determined from willingness to pay surveys conducted by the National Park Service, U.S. Forest Services, and Illinois Parks and Recreation Department. Over thirty years the recreational value is $300,000.

The value of homes that are located in or abut natural open spaces is greater than houses in less aesthetically pleasing areas. This mark-up in price would generate added tax revenue for the City of Worcester. By applying the Hedonic Pricing model, houses in West Tatnuck were considered to be 22% more valuable because of their proximity to the Cascades, Cook's Pond, Tatnuck Brook, and other forested areas.[8] There are one hundred such houses in the area. With the current residential tax rate and the average value of homes in West Tatnuck, the increase in tax revenue would be $487.25 per home or $1,461,750 over thirty years.

[8] Average Based on Bourassa et. Al. (2006), elmcityhomeinspection.com and Luttik (2000)

The total value of the aforementioned services is $2.17 million. This is less than the amount gained from property taxes, $31.8 million, and implies that development is the better option for the City of Worcester for new home in West Tatnuck. The services mentioned above are the maximum value land use planning would assess for the open space. However, this value is incomplete because it fails to account for all the ecological services offered by the forested areas of West Tatnuck. These services combined with the four mentioned above provide a more comprehensive value to the open spaces and makes the case that its preservation is financially sound.

COMPLETE ECOLOGICAL ECONOMIC VALUATION

To properly assess the value of an ecosystem, a more complete valuation must be implemented. Two additional categories of services must be taken into account to achieve this. The value of this complete list is *much* greater than that of the traditionally valued services. If these values were closer together, then the additional categories services could be considered negligible and the economic valuation could be assumed as correct. In the particular case of West Tatnuck there is a large difference between the two.

VALUING REGULATORY SERVICES

The air filtration calculator from CITYgreen requires the model of a city. The city of Worcester was not included in this and thus the model for Providence, Rhode Island was used instead. Providence was chosen based on its proximity to Worcester (44 miles) and its comparative population. Nitrogen Dioxide is technically part of nitrogen (nutrient) cycling but since it was included in the air filtration calculator, it was not used again for the latter service.

Table 4.1: Air Pollutant Removal for West Tatnuck

Pollutant	Pounds Removed per Year	Dollar Value
Ozone	10,486.1	$32,186.54
Particulate Matter	10,422.5	$21,359.13
Nitrogen Dioxide	3,278.5	$10,062.28
Sulfur Dioxide	2,707.5	$2,030.04
Carbon Monoxide	619.2	$264.01
Total	27,513.4	$65,902.75

Table 4.1 illustrates the value provided in terms of each pollutant and amounts to about $65,902 per year. Carbon sequestration was valued using the estimate of $10 per ton which amounted to about $1,000 per year. The total value of air filtration for 30 years was determined to be $2,008,650.

Climate regulation was valued by measuring the amount the average resident of West Tatnuck saves in energy costs. According to a study by MIT, the average rural house saves about 20-25% in energy costs, if it is surrounded by trees that provide shade in the summer and reduce wind speed, mitigating cold air drafts in the winter. A conservative estimate of 15% was used for the homes of West Tatnuck since an ideal situation is not applicable to all the houses. According to Energy Star (2005), the average home spends $1,900 on energy costs per year. The total thirty year worth of microclimate regulation in the region was found to be $6,412,500.

Overland flow mitigation can be valued by the cost to install low impact infrastructure (See Appendix A). Construction costs for swales and roof drainage units were avoided during the construction of the existing 750 homes since adequate runoff mitigation currently takes place in the area. According to McNeil Engineering, the cost for construction and installation of roof drainage units and driveway swales is $3,000 per home. This means the avoided cost for the 750 homes present in West Tatnuck equates to a one time value of $2,250,000. These savings are borne by the existing home owners in West Tatnuck.

The waste treatment provided by the natural resources of the region especially the cascades, is helpful mostly because of the water it affects in Cook Pond and Coe's Reservoir.

The most immediate effect of polluted water in Coe's Reservoir would be the lack of clean water to swim in. The replacement cost involved in installing a public swimming pool was measured to determine the total value for this service. If the City of Worcester were to take on such a project, it would acquire the services of a contractor to do so, which would require infrastructure such as the supply of water and electricity to the surrounding supporting building. The maintenance of a public pool requires the testing of water and cleaning at least twice a month. But since Coe's Reservoir would be closed for recreation in this scenario, the cost currently incurred in this maintenance was obtained from the city's parks and recreation department and subtracted from total value of maintaining a pool. Reviewing many estimates for both of the costs and comparing it to the value given by the department, the value of this service was determined to be $1.5 million initial cost and $52,520 per year which makes the thirty year total $3,105,600.

The real estate value of houses under the flight paths decreases by 0.5% per decibel of ambient noise over 55dB (Nelson, 2003). The homes in West Tatnuck under the flight path are shielded from noise pollution by the forested areas. Currently, the sound levels in the study area are around the 55dB limit. This value would change with the distance from the airport as every 100 feet of trees reduces noise by 7 dB (Coder, 1996). Without this vegetation absorbing the sound, the area would be afflicted with the ambient noise of 60 dB (Kneeland Airport Master Plan Update, 2005). The value of houses in the region would decrease by a reduction of 2.5% which translates to a loss of $21.6 million of gross tax revenue in the study area.

VALUING SOIL BASED SERVICES

Soil is formed by organic matter decomposing into compost. The City of Worcester has a residential leaf collection program. A City Official estimates that the program collects approximately 75,000 to 100,000 pounds of leaves, which translates to 10,000 to 15,000 tons of compost per year. Assuming that the city has a uniform distribution of street tree cover (of which West Tatnuck constitutes 2.73%) and using estimates that compost costs $26 per ton (http://www.epa.gov/compost/basic.htm), this service will produce $7,103 per year and $213,090 over thirty years. This number is flexible because as time goes on the amount of leaves shed by trees in a region will change.

The naturally occurring cycle of nutrients through an ecosystem could be manually replaced by annual application of fertilizer. The major nutrients in West Tatnuck are nitrogen and phosphorus, so the chosen fertilizer must contain these elements. To re-nutrition an acre of land with these elements would cost $65 to $90 (Fristoe & Gothard, 1998). There are 314 acres of land that would need to be fertilized, and over thirty years, assuming yearly application; this would cost $612,900 barring any equipment cost.

Erosion control is the cost to replace erosion resistant surfaces when development occurs. In order to determine this cost, the maximum number of new homes was determined from the build-out data from Central Massachusetts Regional Planning Commission. West Tatnuck is zoned for RS-7 which means that single family homes have lot sizes of 7,000 square feet. The replacement cost for checking erosion would involve putting sod on 5,000 sq ft per lot. Therefore, the cost of 5,000 sq ft of sod and the associated installation costs were determined from numerous sources (Lyons; Smith) and a total sod cost of $2,422.54 per new home was assigned. This meant that $821,241 in costs would be incurred to deter erosion in West Tatnuck.

The comprehensive value of the open spaces gained from accounting for the ecological and economic services is much greater than the amount gained by the typically valued services. The total value for the ecological services that were not initially accounted for but do exist in the natural infrastructure of the region is $37,056,561 which shows the discrepancy between the traditional valuation and a more complete form of valuation. Moreover, the value calculated for most of these services was an estimate on the lower end and a more detailed approach would yield in a higher result. With this taken into consideration it is evident that this is a more accurate method to assign value to the services of an open space.

DISCUSSION

Under current techniques, it would seem reasonable to develop West Tatnuck to the extent formulated by the build out data from the CMRPC, as Worcester would profit more from

Table 4.2: Calculated Totals

	Collected Data			
Ecological Service	Annual Cost ($/yr)	One Time Cost ($)	Long Term Cost ($/30 yr)	Percent Total (%)
Food Production	1,008	-	30,240	0.08
Raw Materials	-	379,129	379,129	0.97
Recreation	10,000	-	300,000	0.76
Cultural	48,725	-	1,461,750	3.73
		Category Total	***2,171,119***	**5.53**
Noise Reduction	721,086	-	21,632,580	55.15
Air Filtration	66,955	-	2,008,650	5.12
Climate Regulation	213,750	-	6,412,500	16.35
OLF Mitigation	-	2,250,000	2,250,000	5.74
Waste Management	53,520	1,500,000	3,105,600	7.92
		Category Total	***35,409,330***	**90.27**
Soil Formation	7,103	-	213,090	0.54
Nutrient Cycling	20,430	-	612,900	1.56
Erosion Control	-	821,241	821,241	2.09
	* 314 Acre Approx.	***Category Total***	***1,647,231***	**4.20**
		Service Total	**39,227,680**	

the taxes on the newly built houses than value of the natural resources, recreation, and hedonic properties. The deficit between these two figures over thirty years is $29.6 million; a large deficit considering this is 93% of the additional tax revenue of the city. With the conventional valuation approach development of West Tatnuck would be largely profitable. This system is flawed, however, as is evident by the data gathered in regards to the complete list of ecological services.

Over thirty years Worcester would gain $31.8 million in additional tax revenue from West Tatnuck, while the ecosystem as it stands now will be worth $39.2 million over the same period. The new valuation method is more thorough in regards to open space as it puts forth a more accurate depiction when considering development. Through this evidence it can be seen that conventional economic lacks a broad enough mechanism to value open space and, at least in the development decision process, should be replaced with a more ecological economic approach.

5: Conclusion

Through an in-depth analysis of valuation techniques, this project made three major findings. The first found that the methods by which the economy values property often undervalues natural open space, as it fails to account for the larger benefits of ecological services to communities. Next, the comprehensive methods of ecological economics were applied at a local scale to gain a complete value for the study area of the project. Finally, by assessing this value, the benefits of natural open space were given a tangible face to the community, which is more concrete than speaking of the "inherent" value of nature. These points support the cause of groups like the Greater Worcester Land Trust by giving them something substantial to use in conservation efforts.

Typical development consideration would compare the maximum economic value of a parcel of land (based on the highest and best use, such as build out to the maximum number of residential units) to the value of the amenities and natural resources provided by the parcel in its undeveloped state (such as lumber and food production). In the case of West Tatnuck the maximum value is fourteen times greater than the value of the currently recognized services. Because of this, large-scale development in West Tatnuck would seem worthwhile. It is only when a more comprehensive approach is taken that the actual value of the ecological services of an area can be accurately determined.

The ecological economic valuation method accounts for all of the services present on a given piece of land, thus it is more complete than the traditional economic approach. There are twelve such services present in West Tatnuck that were evaluated in this project (air filtration, cultural, erosion control, food production, microclimate regulation, noise reduction, nutrient cycling, overland flow mitigation, raw materials, recreation, soil formation, and waste treatment). After determining particular valuation techniques for each service their values were calculated. The total value for all the twelve services was seventeen times larger than the value that economists would typically assess. This fact points to the major flaw in the traditional valuation approach.

The most significant result of this project found that the net revenue from the full development scenario of West Tatnuck was less than the ecological economic value. The ecological economic value is a baseline minimum and the conventional economic value is at a maximum. If a more detailed approach to this project was undertaken, the change in values would, at most, widen the difference between the revenue from the two scenarios. In either case, the full valuation of the neighborhood makes a case for conservation of its open spaces.

It is the recommendation of the project team that similar diligence is taken in assessing value for parcels of land that are considered for conservation as was taken by this project. When applied to a comparable scale, the outlined methods to more accurately assess the practicality of development over a given piece of land. Though the focus of this project was on ecosystems, it does not discourage development; however it suggests a more thorough analysis of what is financially sound for a given area. If enough care is taken municipalities would not have to pay for ecological services in the future and avoid burdening infrastructure costs. By this analysis development can still occur in the right places, while open space is preserved where appropriate. The case study of West Tatnuck revealed that there is more to land use planning than just an economic value, because of this a full assessment of this value would account a complete list of ecological services.

From these findings we recommend the following areas of further research:

Improving models for valuation: The project's focus on valuing West Tatnuck in particular resulted in some loss of generalities. A research focus on establishing a clear methodology for any parcel of land would make such valuation substantially easier.

Applying the models in the Greater Worcester Area: The Greater Worcester Land Trust owns many more open spaces similar to West Tatnuck and the application of models could enable more conservation efforts.

Determining better tools for preserving ecological services: The current land use planning tools are out dated and not suited for preservation of ecological services. Newer methods like Low Impact development take advantage of one of the services (overland flow mitigation) and other similar methods could benefit from more without stopping development completely.

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APPENDIX A: TOOLS TO COMPLEMENT ECOLOGICAL SERVICES

With the proposed shift in the valuation approaches, it is important to point out ways in which ecological services can be protected. The first two methods focus mainly on the individual impact to ecosystems and thus attempt to slow it by punishing or rewarding individuals. Zoning is well established and more regulatory while incentives are not. Another school of thought claims that the ecosystem functions can still be present with development. This practice, known as low impact development, may be a better choice to maximize the effectiveness of ecological services. This section will focus on all the possible tools that can be used by urban planners for protection of ecological services.

ZONING REGULATIONS

Zoning regulations can be changed to preserve ecological services. Zoning ordinances work by restricting land use to residential, industrial or commercial uses. The traditional purpose behind these ordinances was derived from an economic perspective and focused mainly on the balance between residential and business sectors, where the importance of natural spaces was often overlooked. For example, according to the zoning ordinances of Worcester, one of the primary purposes of zoning is to protect the socio-economic needs and other general welfare of the people (Worcester Zoning Ordinance, 2007). The protection of natural and historical sites is a lower priority. One of the potential benefits of this project would be to convince the Worcester Zoning Board to take natural services more seriously and make their protection a higher priority.

According to Wheeler (2004), zoning is ubiquitous in the United States and thus can be used as a tool to serve a different purpose. Besides the three broad categories mentioned above, the crux of zoning is in the detailed plans on the minimum size of the lots, setbacks from public roads, number of stories, etc. The basic idea of these ordinances can be extended for the protection of ecological services. For example, zoning could require minimum percentage of land to be permeable to soak up water runoff that would otherwise add to non-point source pollution. Another example is to zone regions for open spaces to provide ecological services such as microclimate regulation, air filtration, and noise reduction.

INCENTIVES AND DISINCENTIVES

Market based approaches can also be used to protect ecological services. The government can provide financial incentives to promote desirable activities. Jacobs (1991) offers a description, "Subsidies provide positive incentives. Placing a tax on damaging activities such as energy consumption or waste emissions alternatively creates a disincentive to undesirable behavior" (p. 123). Incentives have the advantage of raising awareness of ecological services and encouraging proactive actions toward their protection in a non-coercive form. Disincentives on the other hand discourage destructive development while generating revenue for the city.

While both of these financial actions have their advantages, there are also limitations. Market based initiatives are not as effective as a more comprehensive plan because they stress the importance of the individual contribution to the ecosystems. Gottfried, Wear, and Lee (1996) points out that, "individual owners acting alone cannot provide the socially optimal mix of ecologically-provided goods and services" (p. 136). An ecological economic analysis would reveal that the long term and long distance effects to the ecological services cannot be factored in through the traditional approach. For example, in the case of pollution, subsidies and penalties cannot be applied to non-point source pollution. Also, incentives may not be feasible since many cities do not have the financial backing to provide for effective subsidies. Interaction at a larger scale by the government may be required since planned development of regions would be more fruitful for ecological services than staggered individual growth, even with the use of financial incentives.

LOW IMPACT DEVELOPMENT

The focus on the individual's effect on the ecosystem may not provide the best blend of ecological services and urban development. A more comprehensive planning that focuses on the interaction of the ecosystem and the surrounding community would be better suited since for this purpose. According to Gottfried et al. (1996) the methods outlined previously (zoning and incentives) do not take the full scale (space and time) of interaction into consideration. A comprehensive plan would allow development of a parcel of land while still maintaining many of the ecosystem functions.

One example of comprehensive planning that takes ecological services into account is Low Impact Development. One of the crucial ecological services provided by unpaved open space, especially in a heavily contoured city, is that of overland flow mitigation. A new design concept known as Low Impact Development (LID) is one solution. The idea behind LID is to have the runoff water absorbed on site rather than flow through pipes. The basic premise is to have enough permeable surfaces that can absorb the load from non-permeable surfaces. Water can also be stored in containers and reused or stored in large tanks, then released at some intervals (Upchurch, 2005, p. 11). Such a development can have a measurable impact on storm water management. The study by Hood, Clausen, and Warner (2007) that compared the storm water peak discharges and other variables found that, "LID resulted in lower peak discharge depth . . . and increased lag times and runoff threshold compared with traditional residential development." (p. 1). LID is an example of what an ecological economist would consider valuable and effective use of ecological services.

Table A.1: Tool Comparison

Tools	Pro	Con
Zoning Regulations	*Widely Accepted*	*Restrictive, Limited Range*
Incentives	*Non-Coercive*	*Individual, Expense to City*
Disincentives	*Generates Revenue for City*	*Individual, Slightly Coercive*
LIDs	*Ecologically Sound Development*	*Expensive, Specialized*

To implement the value system of the ecological economics the laws, regulations, and planning structure would have to be altered. Moreover the government may need to stimulate more planned regions such as with LID that goes beyond the protection of or the punishment to individuals. Presently, most state and local laws and regulations reflect the views of traditional economy. The protection of ecological services is a byproduct of a larger scale movement to conserve the environment as a whole. Specific policies are needed to protect the services themselves. Ecological Economists and some communities are trying to amend them so that ecological services have a more important role in urban planning.