

Linking Sudden Oak Death With Spatial Economic Value Transfer¹

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Abstract

Sudden oak death (caused by *Phytophthora ramorum*) is currently having a dramatic impact on the flow of ecosystem services provided by trees and forests in California. Timber species in California are not thought to be at risk of mortality from this pathogen and, consequently, economic impacts accrue to non-market values of trees such as aesthetics, shading, and the knowledge that healthy forest ecosystems exist. Because non-market valuation studies are expensive to design and implement, we propose that spatial benefit transfer methods can be used as a pragmatic means for obtaining second-best estimates of the economic damages associated with *P. ramorum*. Economic damages to residential property values and public forest land are identified as a major concern.

Key words: Economic impacts, non-market values, value transfer, hedonic property value, contingent valuation, existence value, GIS.

Introduction

Forests provide suitable habitat for an assortment of invading organisms (Liebhold and others 1995) and invasive species have been ranked as one of the four critical threats to our Nation's forest ecosystems by the Chief of the United States Department of Agriculture-Forest Service (USDA-FS) (USDA Forest Service 2004). Although most people might argue that it is laudable to counter threats to the structure and functioning of forest ecosystems, relatively few exotic organisms become a major pest (Williamson 1996). It is the main thesis of this paper that decisions regarding budget allocations and the targeting of forest protection efforts would benefit from a clear understanding of the costs and benefits of invasive forest pest management (Holmes and others 2007). Interventions designed to mitigate damages from exotic forest pests are costly - the USDA-FS spent \$95.1 million dollars for the management of invasive forest pests in fiscal year 2005 (USDA Forest Service 2005, p. 14 to 55). However, very little is known about the magnitude of economic damages caused by exotic forest pests, or the efficacy of the money spent on pest control. This lack of knowledge impedes economic analyses of pest management programs and it remains unclear whether current expenditures on invasive forest pests are too little, too large, or about right.

Economic damages are incurred when invasive forest pests alter the flow of ecosystem services provided by trees and forests which are valued by people. Forest ecosystem services can be broadly categorized as services that are traded in markets (such as timber) and non-market-based services (such as aesthetically pleasing views). Market and non-market values can be evaluated using consumer and

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producer surplus concepts drawn from welfare economic theory. In instances where data are not available on the supply of, or demand for, economic goods and services, other non-welfare-theoretic methods may be adequate. Although it is often tempting to sum various economic measures to arrive at an aggregate estimate of damage, it is important not to sum economic measures that are based on different conceptual foundations. Likewise, it may not be meaningful to compare damage estimates computed using widely divergent economic methods.

Perhaps the most widely cited estimate of the aggregate damages from exotic forest pests (\$4 billion per year) is due to Pimentel and others (2000). Their measure was computed by multiplying the price of timber by an estimate of the annual quantity of timber destroyed using pest loss rates estimated for Canadian forests. Their measure does not include the broader impacts of forest pests on non-market economic values and is therefore biased downwards, perhaps severely. For example, using such a methodology, the forest ecosystem disturbances occurring in California and Oregon from *P. ramorum* infections would not be causing any economic damage as important timber species in this region are not thought to be at risk of loss from this pathogen (Rizzo and others 2005). Other approaches are clearly required to estimate the economic damages associated with the loss of hundreds of thousands of trees in private and public landscapes currently being killed by this pathogen.

Spatial Benefit Transfer Methods

In this paper, we propose the use of benefit transfer methods for estimating the non-market value losses attributable to the spread of *P. ramorum* in California. The logic for using benefit transfer is pragmatic - non-market valuation studies are expensive to design and implement. When funds are unavailable for collecting primary data for a non-market valuation study, benefit transfer may provide a reasonable second-best alternative.

Broadly speaking, a benefit transfer uses estimates of economic value derived from research conducted at a study site and transfers the estimates to a policy site of interest. Various methods are available for conducting a benefit transfer study and which method is used depends upon the data available and the goals for conducting the transfer (Rosenberger and Loomis 2003). The *value transfer* approach directly applies summary statistics from the original research to the policy site. This approach would typically use a point estimate, some measure of central tendency, or an administratively approved estimate of value. The *function transfer* approach is more technically demanding than a simple *value transfer* as it involves the transfer of statistical models defining functional relationships between variables. Examples of this method would include the use of demand or willingness-to-pay (WTP) functions as well as meta-analysis regression functions. *Function transfers* may be more informative than *value transfers* as they can facilitate adjustments that account for salient characteristics at the policy site. Both the value and function transfer approaches require the acquisition of data from existing studies which may be identified in published and unpublished literatures.

The damage caused by invasive species is intrinsically spatial in nature and identifying the spatial incidence of damages improves the calibration of benefit transfer estimates, especially when damages occur over broad geographic areas and

land uses. Although most benefit transfer studies have been non-spatial, the increasing prominence of Geographic Information System (GIS) technology is advancing the ability to conduct spatial value transfers. Eade and Moran (1996) provide an early example of spatial value transfer by mapping the quality of natural capital assets in Rio Branco, Belize and then re-calibrating benefit transfer estimates using the quality maps. Bateman and others (2002) describe how travel cost assessments of recreational value can be transferred using the analytic capabilities of a GIS. More recently, Troy and Wilson (2006) developed a typology of land cover and aquatic resources which were spatially linked with economic valuation studies in three study sites.

At a landscape scale, trees and forests provide a heterogeneous array of ecosystem services. Humans recognize and value some sub-set of this array. A linkage between ecosystem services and economic value is provided by the recognition that human land uses reflect decisions about the provision of goods and services valued by people. For example, people choose to live in certain areas of the overall landscape, work in other areas, and set aside special locations for public use or scientific study. Within each of these land uses, forest ecosystem goods and services (such as trees) are managed and valued differently. Thus, one method of linking the flow of forest ecosystem services with economic values across a landscape is to identify the relationship between ecosystem characteristics, land-uses, and economic value.

Recognizing that economic values are not absolute, but rather represent the value of changes from a starting point or *status quo* state to an alternate state, the approach we recommend in this paper is to evaluate how changes in forest ecosystem characteristics alter the value of non-market good and service flows within separable land uses. In particular, the spatial benefit transfer method we propose is based upon a simple algorithm for identifying linkages between land uses, forest disturbances caused by *P. ramorum* and non-market economic damages:

$$Economic\ damage_i = [(Area_i) \cap (SOD)] * (value\Delta_i) \quad \forall i \quad (1)$$

where $Area_i$ is the area in land use type i , SOD is the area of *P. ramorum* infestation, $value\Delta_i$ is the value change in land use type i resulting from *P. ramorum* infection, and $\cap$ is the intersection operator. It is important to note in equation (1) that economic impacts are computed separately for each land use category and yet are not summed across land uses. This is because economic estimates of value changes in forest health provided by the economics literatures are partial (rather than general) equilibrium impacts. Because the degree of interaction between forest health value on different classes of land use are unknown, summing the values across land use classes would lead to a biased estimate of aggregate impact unless the degree of interaction between land use classes is known to be zero. As we are unaware of any studies estimating the linkages between forest health values across land uses, we recommend evaluating each land-use class separately. None-the-less, categorical estimates can provide an indication of the relative importance of changes in forest health on various land use classes of interest as long as estimates are based on the same theoretical foundation.

Data Requirements

Three types of data are required to implement the economic value transfer method as shown in the above equation: (1) economic value estimates drawn from studies conducted at original study sites, (2) GIS data on forest health conditions in the policy area, (3) GIS data on land uses in the policy area. Each data requirement will be discussed in turn.

Economic Value Transfer Data

The economic literature on the non-market economic value of trees and forests has been focused primarily on the value of trees in residential and public landscapes. Consequently, the studies we briefly review are thought to be representative of the non-market economic values that trees add to urban and public forests.

Data Assessed With the Hedonic Property Value Method

One method of evaluating the economic impacts of invasive species on residential properties is to use econometric methods to tease out the change in property value due to a change in tree numbers or a decline in tree health while controlling for all other factors influencing housing prices. This method, known as the hedonic property value method (HPM), has the advantage of utilizing data on actual economic transactions. Several economic studies have been conducted using (HPM) to estimate the contribution that trees make to private property values in residential landscapes (table 1). An early study was provided by Morales and others (1976) who found that tree cover added about 6 percent to property values in Manchester, Connecticut. A similar result was reported by Anderson and Cordell (1988) who concluded that trees in the front yard of homes in Athens, Georgia added about 3 to 5 percent to housing prices relative to houses without trees (and each large front yard tree added about 0.88 percent to property value.)

Payne and others (1973) estimated that, on average, each large tree (> 6 in. [15.24 cm] dbh) added about \$270 to property value in Amherst, Massachusetts. They also reported that the value arc elasticity (ϵ) for trees was 0.24. This means that a 1 percent increase (decrease) in the number of trees increases (decreases) property value by 0.24 percent. A somewhat larger arc elasticity ($\epsilon = 0.66$) was found by Holmes and others (2006) for healthy hemlock trees on properties in Sparta, New Jersey.

In general, the available economic literature indicates that trees add, on average, from 1 to 5 percent to the value of private property in a residential setting. This stylized fact is consistent with Dombrow and others (2000) who, using tree appraisal methods, found that mature trees contributed about 2 percent to the value of single-family homes in Baton Rouge, Louisiana. Note that these values provide an estimate of the value of trees as a “stock” or asset value which, in turn, provides a flow of services over time. An estimate of the “flow” (for example, annual) value of residential trees would need to adjust these estimates for the length of time over which trees provide this service.

If trees make a positive contribution to property values then, presumably, factors that cause the demise of trees will reduce property values. However, it is not obvious that the loss in value due to either a loss in tree health or numbers will be symmetric with

an equivalent gain in health or numbers. Consequently, measures of the loss in property value due to a loss of tree health would improve the precision of economic damage estimates. We are only aware of two studies that directly estimate the loss in private property values from a decline in forest health. Holmes and others (2006) studied the impact of an exotic forest insect, the hemlock woolly adelgid, on property values in Sparta, New Jersey (table 1). They found that hemlocks with declining health decreased property values both for the property owner as well as having spill-over impacts on other properties in the neighborhood. Notably the absolute value of the (negative) value arc elasticity ($\varepsilon = 0.96$) for hemlocks in declining health was greater than the arc elasticity (positive) for healthy hemlocks ($\varepsilon = 0.66$). In a related study, conducted with a richer dataset in West Milford, New Jersey, Huggett and others (2007) found that property values decreased substantially during the later stages of hemlock woolly adelgid infestations when most hemlocks were either dead or dying. Their estimates show that for each 1 acre (0.4 ha) increase in dead and dying hemlocks, property values were reduced by about 8 percent in this housing market. Further, this study indicates that the major economic impact of a change in forest health occurs when most of the host trees are dead or dying. Thus, the time dimension is critical when estimating economic impacts.

Thompson and others (1999) used the hedonic pricing method to evaluate the change in private property value in Lake Tahoe, California resulting from tree mortality due to native insect infestations. In particular, their methodology estimated the change in property value due to thinning and removal of dead and dying trees. They identified substantial gains in value (1 to 30 percent) which were attributed to both improved visibility and a reduction of fire hazard.

Data Assessed With the Contingent Valuation Method

A second method for estimating the economic value of changes in forest health is to use surveys to elicit stated values from a random sample of the population. This method, known as the contingent valuation method (CVM), has the advantage that it is the only method capable of eliciting existence values, or the value of knowing a resource (such as a healthy forest) exists, even if one never anticipates visiting that resource. Although the CVM is typically used to estimate the non-market economic value of public resources, Walsh and others (1981a, 1981b) used this method to estimate the reduction in private property values in the Rocky Mountains of Colorado due to infestations of native forest insects. Contingent valuation surveys were implemented via interviews both with private property owners and with real estate appraisers. Estimates of value arc elasticity were similar across groups and indicated that a 1 percent increase in the area of visible damage from native forest pests results in 2.3 to 2.5 percent reduction in property value.

The CVM has also been used to assess the economic impacts of changes in forest health on public forest land. Several analyses have been conducted using contingent valuation data that were collected to evaluate public WTP to protect high elevation spruce-fir forests in the southern Appalachian Mountains from the exotic balsam woolly adelgid (BWA). These analyses (Haefele and others 1992, Holmes and Kramer 1995, Holmes and Kramer 1996, Kramer and others 2003) indicated that: (1) median annual household WTP for BWA protection programs ranges from \$28 to \$36 and, (2) existence value is an important component of total forest value.

Table 1—Sources for non-market economic valuation of trees and forests

Value type & location	Annual benefit/ loss	Economic unit	Economic method	Data source
Private property value				
Healthy trees				
Connecticut	6 percent house value	Urban forest tree numbers	HPM	Morales and others (1976)
Georgia	3 to 5 percent house value (0.88 percent per large front yard tree)	Urban forest tree numbers	HPM	Anderson & Cordell (1988)
Massachusetts	$\varepsilon = 0.24$ house value	Urban forest tree numbers	HPM	Payne and others (1973)
New Jersey	$\varepsilon = 0.66$ house value	Ex-urban forest tree area	HPM	Holmes and others (2006)
Louisiana	2 percent house value	Urban forest tree numbers	Tree appraisal	Dombrow and others (2000)
Dead and dying trees				
New Jersey	$\varepsilon = 0.96$ house value	Ex-urban tree area	HPM	Holmes and others (2006)
New Jersey	8 percent house value (per ac.)	Ex-urban tree area	HPM	Huggett and others (in press)
Colorado	$\varepsilon = 2.27$ house value	Rural visible damage	CVM – owners	Walsh and others (1981a)
Colorado	$\varepsilon = 2.48$ house value	Rural visible damage	CVM – appraisers	Walsh and others (1981b)
California	1 to 30 percent house value	Thin unhealthy trees in resort area	HPM	Thompson and others (1999)
Public forest value				
Healthy trees				
California	\$477/ tree	Urban forest tree numbers	CTLA	Nowak and others (2002)
California	\$27.12/ resident \$54.33/ tree	Urban forest tree numbers	Various	McPherson and others (1999)
Dead and dying trees				
North Carolina	Median WTP = \$28 to \$36/ hhd.	National Forest/ Park area	CVM – households	Holmes and Kramer (1996); Kramer and others (2003)
Colorado	Mean WTP = \$52/ hhd.	National Forest area	CVM - households	Walsh and others (1990)

Note: HPM refers to the hedonic price method, CVM refers to the contingent valuation method, CTLA refers to the Council of Tree and Landscape Appraisers.

In a similar study, Walsh and others (1990) used the contingent valuation method to estimate public WTP to protect national forests in Colorado from native insect infestations. Their value estimate (average annual household WTP = \$52) was similar to the values reported for the southern Appalachian Mountains. In addition, they reported that non-use values dominated the estimates of use value. Taken together, these studies indicate that the public holds a significant willingness to pay for forest health protection on public lands, and that non-use values are an important component of total economic value.

It should be pointed out that the contingent valuation method is not without its critics, and that criticism stems largely from the fact that WTP estimates are based on stated

intentions rather than actual expenditures. Further, forest health protection studies conducted using the contingent valuation method have not fully incorporated the dynamic nature of forest disturbances. That is, forest succession will follow some (perhaps largely unknown) pathway following mortality due to either native or exotic forest pests. Thus, WTP estimates need to take this dynamic into consideration. Finally, because WTP estimates are typically estimated for households, an estimate of aggregate impact requires that the “extent of the market”, or the number of households holding a positive WTP for the public forest at risk, be determined.

Data Assessed With Accounting Methods

Finally, it should be recognized that a few studies have been published that seek to estimate the value of trees in the urban forest using accounting methods. These studies are conducted using either a tree appraisal approach (for example, Nowak and others 2002) or mixed methods (for example, McPherson and others 1999). Tree appraisal methods use a formula to estimate tree value based on the physical characteristics of a tree. Although tree appraisal methods are not based on theoretic economic models, they appear to provide fairly similar estimates to the hedonic pricing method when applied to residential properties. The application of tree appraisal methods to other land uses, such as the value of street trees, cannot be similarly compared to theoretic economic models because we are unaware of such studies. Other studies that use mixed methods for valuation estimate an aggregate value of trees in the urban forest by summing values for the various services that trees provide, such as aesthetics, shading, and moderating water runoff. As noted above, the summation of values estimated using dissimilar methods (such as hedonic property values and estimates of energy savings from the cooling function of trees in summer) is not consistent with standard economic theory.

Forest Health and Land Use GIS Data

A review of the non-market economic value studies above provides us with an indication of the types of forest cover and land use data that would be required to conduct an economic value transfer study. To match up with the economic value data, GIS forest health data would need to be available for the policy site(s) that include the spatial location and area, number, or percentage of trees that are hosts for the pathogen, metrics concerning the area, number, or percentage of trees that are currently infected, and the anticipated rate of spread. In addition, as the economic literature suggests that economic impacts are most pronounced during the period of time when host trees are dead or dying, spatially reference data would be required for the timing and location of tree mortality induced by *P. ramorum* dispersal.

The land use data required for economic value transfer would include GIS data depicting the location and area of tree hosts on land uses such as urban residential properties (for transfer of HPM values) and public lands such as local, state, and national parks and forests with tree species that are at risk of mortality from *P. ramorum* (for transfer of CVM values). Remote sensing data have proven to be successful in mapping *P. ramorum* incidence in California at fine spatial resolutions (Kelly and Meetenmeyer 2002).

An example of the type of GIS data required for economic value transfer are GIS data showing the location and perimeters of concentrated confirmed areas of *P. ramorum* infected vegetation which were first published in January, 2002 by the sudden oak

death project, Center for Assessment and Monitoring of Forest Environment Resources (CAMFER), University of California Berkeley (figure 1). Data on land use classes are also available on the same website. The data show 22 distinct areas of *P. ramorum* infestation within Marin County, California which range in size from 46.2 to 10,126 ha, and total approximately 30,568 ha countywide. Of this total, approximately 15,002 ha fall within local, state, and federal park land and 11,349 ha fall within the urban residential land use class (greater than 1 housing unit per acre). Estimates of the average annual number, area, or percentage of trees that die from *P. ramorum* infections would allow estimates of non-market economic losses to be computed. A good example is provided by Kelly and Meetenmeyer (2002) who estimated that about six dead and dying trees per hectare could be identified in and around China Camp State Park in Marin County, California.

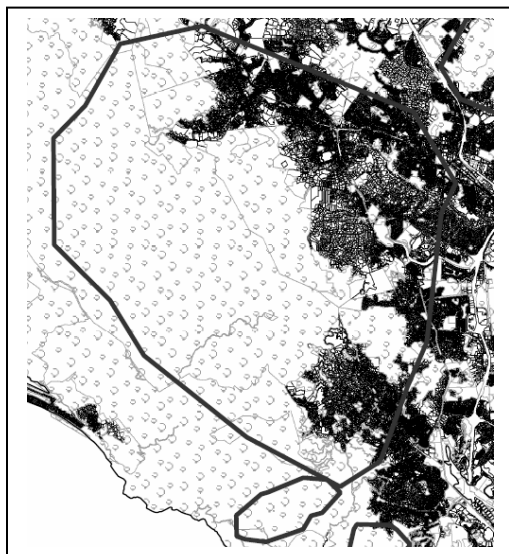


Figure 1—GIS map showing concentrated confirmed areas of *P. ramorum* in the San Raphael – Novato community, Marin County, California. The approximate perimeters of infested areas are shown as grey polygons. Darkly shaded areas are urban parcels, and the lightly shaded areas are public parks.

Conclusion

This paper argues that economic value transfer methodology can be used to provide second-best estimates of damages to non-market economic values associated with changes in forest health due to *P. ramorum* infections in California. This research program requires data on non-market values provided by the literature in combination with spatially reference GIS data showing the location of trees currently infected with the pathogen, regions at risk of future dispersal of the pathogen, anticipated rates of dispersal, and estimates of mortality rates. Although it is thought that the value transfer methodology could be used to evaluate the non-market economic impacts of *P. ramorum* throughout California, it is recommended that a preliminary evaluation of this method be conducted by completing a spatially explicit economic value transfer in one or a few counties of the state that are currently experiencing severe impacts from this exotic forest pathogen.

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