A Benefit Transfer Estimation of Agro-Ecosystems Services

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Introduction

Agricultural land supports not only the production of food and fiber, but a variety of socially valuable non-market goods and services. Examples of those non-market goods and services include aesthetic experiences, wildlife habitat, carbon sequestration, and recreation to name a few. There is a growing awareness of the importance that provision of these non-market services has to the long-run sustainability of agriculture in general, and the sustainability of California agriculture in particular. This awareness has led to an increasing interest in the estimation of the ecosystem functions of non-market goods and services of agriculture.

As the ecosystem services are typically not traded in markets and do not carry an explicit market value, they are improperly quantified and often inadequately considered in policy decisions (Costanza et al.'s 1997). Calculating their actual value is a complex undertaking that requires finding an integrative metric that can link these services to human welfare (Pattanyak and Butry, 2005). Value estimates of the ecosystem goods and services can be obtained by relying on two approaches: a) cost-based methods that price these services according to their provision costs, and b) demand-side valuation methods that generate estimates of the willingness to pay or the consumer surplus related to a change in the provision level of these services (Madureira *et al*, 2007). Table 1 summarizes these methods and gives a short description of each category.

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Table 1: Approaches and Methods for Environmental Economic Valuation

Valuation Approach	Valuation Methods	Description
Cost-side	Replacement Cost	Costs of replacing environmental assets and related goods and services (e.g. replace soil fertility due to soil contamination)
	Restoration Cost	Costs of restoring environmental assets and related goods and services (e.g. restore soil fertility through soil decontamination)
	Relocation Cost	Costs of relocating environmental assets and related goods and services (e.g. moving existing habitats to alternative sites)
	Government Payments	Government payments for the provision of environmental goods and services (e.g. agri-environmental measures)
Demand-side Revealed preference Methods	Travel Cost Method	Estimates the demand for a recreational site using travels costs as a proxy to the individual price for visiting the site
	Hedonic Price Method (HPM)	Estimates the implicit price for environmental attributes through the individuals choices for market goods which incorporate such attributes (e.g. estimate implicit price for air quality in the price of a house)
	Averting Behavior (AB)	Estimates the monetary value for an environmental good or service observing the costs individuals incur to avoid its loss (e.g. buying water filters to assure safe drinking water)

Despite the relevancy of ecosystem evaluation, the existing empirical literature on this topic is scarce. It is limited to a few studies for each type of ecosystem or service (Pattanayak and Butry 2005, Pagiola et al. 2004), as the application of these primary evaluation methods is costly both in terms of time and financial resources. One way to take advantage of the benefits of primary research, while minimizing the use of resources is to rely on the benefit transfer method.

Benefit transfer methodology (BTM) represents a growing area in environmental economics research that has been fueled by the needs and demands of policy makers for estimates of non-market environmental goods benefits. Benefit transfer is a formal process whereby the stock of knowledge, rather than original research, is used to inform decisions (Loomis, 1992). Economic information from one place (a ‘study’ site where data are collected) and time is used to make inferences about the economic value of environmental goods and services at another place (a ‘policy’ site with little or no data) and time (Rosenberger and Loomis, 2000).

BTM took form as a separate method once the non-market valuation literature grew large enough to allow comprehensive synthesis and cross-study comparisons. It has matured in the last two decades into a viable approach for estimating the ecosystem benefits. BTM has been used more and more frequently by various bodies and organizations including government agencies to facilitate benefit-cost analysis of public policies and projects affecting natural resources (Bergstrom and DeCivita,1999, Colombo et al., 2007, Wilson and Hoen, 2006).

This paper illustrates the use of BTM for estimating the non-market benefit of goods and services provided by an agro-ecosystem. The site selected for this analysis is Kern County, California. This county was selected due to its geographic diversity and available data sources. Kern County is located in the southern San Joaquin Valley and encompasses an area of about 8,171 square miles or 5,229,440 acres, making it the third-largest county in California. The county is well-endowed with mineral resources and fertile land allowing for agricultural production to be a significant economic activity. Kern County has a population approaching 800,000 and is expected to continue population growth over the next 20 years. This increase in population is expected to exert pressure to convert agricultural land to housing, industrial, and commercial uses. Thus, it becomes increasingly important to determine the benefits of the agro-ecosystem goods and services provided by agricultural land, in order to determine appropriate land use policies. If this is not done, then it is possible that a significant yet, currently unaccountable and non-quantified portion of the total economic benefit of Kern County agricultural land base will not be considered in land use planning.

Benefit Transfer Estimate of Kern County Agro-Ecosystems Goods and Services

The estimation of the Kern County agro-ecosystem goods and services benefits begins with the GIS mapping of various land cover types. Data on the land categories used in this study were obtained from California Spatial Information Library, U.S. Fish and Wildlife's National Wetlands Inventory, and County of Kern Department of Agriculture/Measurement Standards. Table 2 present data on acreage and percentage of 13 land types present in Kern County as determined by the GIS analysis[2]. Figure 1 shows a map of Kern County land typology as developed by the authors of this study.

Table 2: Land Cover Typology for Kern County, California

GIS CODE	Land Type	Area (Acres)	Percentage of Land Type
AGR	Agriculture	1,209,465	23.0
CON	Forest-Conifer	176,688	3.0
DSHB	Desert Shrub	1,338,701	25.0
DWLD	Desert Woodland	7,141	01
FWET	Fresh wetland	52,265	1.0
HDW	Hardwood oak woodland	334,417	6.0
HEB	Herbaceous	1,254,210	24.0
MIX	Mixed hardwood, conifer	61,936	1.0
RIPF	Riparian Forest	151,051	3.0
SHRB	Shrubs	381,174	7.0
URB	Urban and Barren	218,278	4.0
URBG	Urban Green	94,143	2.0
WAT	Open Fresh Water	41,729	1.0

[2] A description of the GIS process used to provide the land type covers necessary to estimate the ecosystem services value associated with each can be obtained directly from the authors.

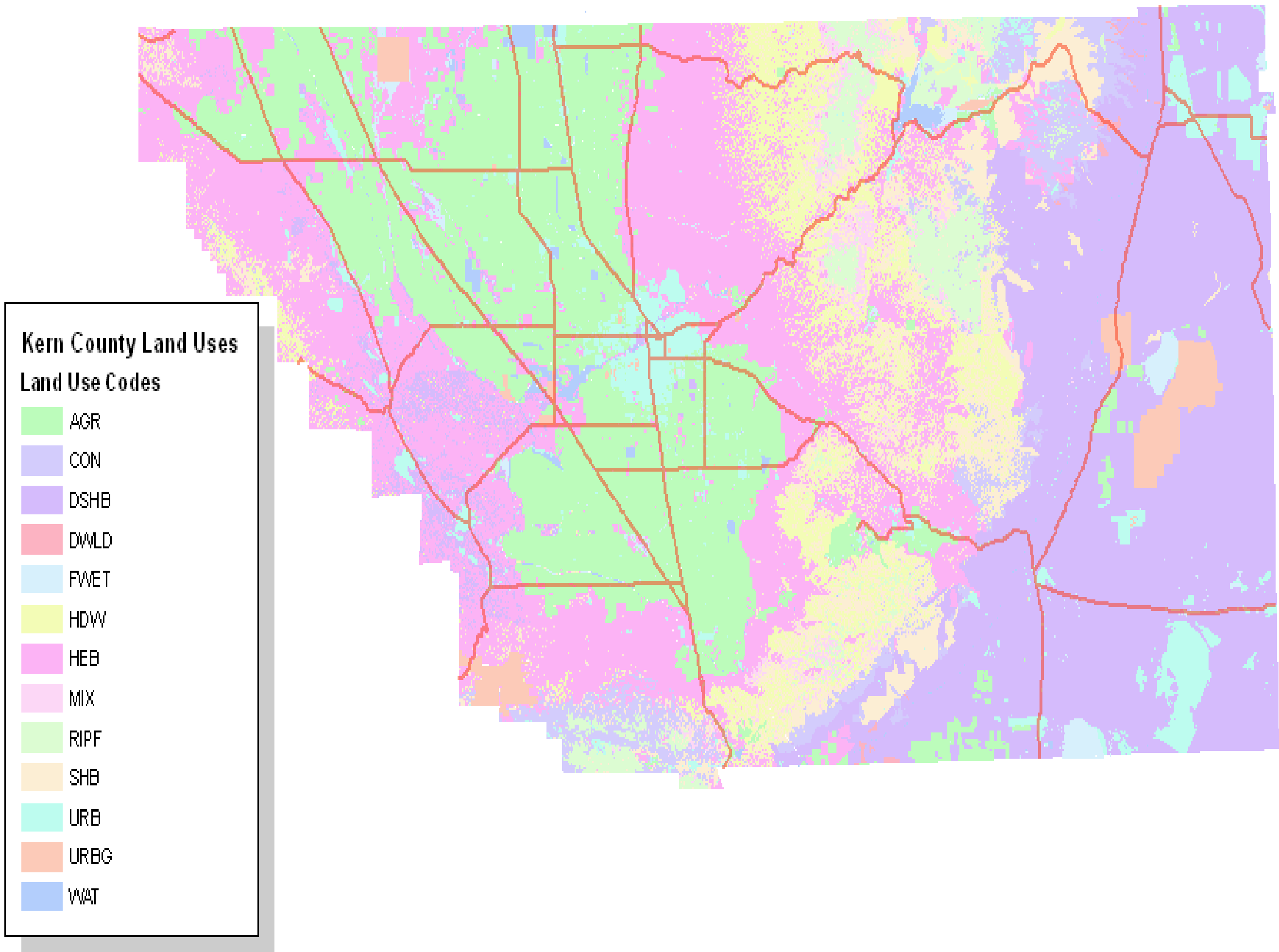

Figure 1. Map of 13 land categories in Kern County, California

Once the mapping of the land types for the study area has been completed, the ecosystem goods and services areas were overlaid on GIS mapping of land types to determine the acreage of each ecosystem good and service associated with each land type. The next step in the estimation of the agro-ecosystem goods and services benefits is the determination of the ecosystem goods and services benefit transfer values. This study uses benefit transfer values generated by Troy and Wilson (2006) and TSS Consulting (2005). These studies provide a set of unique standardized ecosystem service value coefficients broken down by land cover class and service type. The area included in Troy and Wilson study represents rich landscape heterogeneity that is sufficiently representative of most of California's major biomes to allow transferability of results to other parts of the state. To generate these benefit transfer estimates, Troy and Wilson considered preexisting studies published in peer reviewed journals, focused on temperate regions in North America, Canada and/or Europe, and focused primarily on non-consumptive use. They were able to obtain data from 84 viable primary valuation studies using these search criteria,. After coding these data points by temporal (i.e., time of study), spatial (i.e., place where study was done) and methodological (i.e., method used) criteria a lower bound, an upper bound and an average estimate of dollar values for the study site were derived.

Table 3 reports the available estimates by land cover type and ecosystem services that were used by Troy and Wilson to generate benefit transfer value coefficients. The numbers in white cells show that a total of 205 individual ecosystem value estimates were able to be obtained from the peer-reviewed empirical valuation literature for the land cover types included in this study. Areas shaded in grey represent cells where a service is anticipated to be provided by a land cover type, but for which there is currently no empirical research available. Given the aforementioned restrictions and gaps in the available literature, these values should be considered as providing a conservative, baseline economic values for the study area.[3]

Table 3: Gap of Estimates Matrix

ESS\LAND COVER TYPE	AGR	CON	DSHB	DWLD	FWET	HDW	HEB	MIX	RIPF	SHRB	URB	URBG	WAT
Gas & Climate Regulation		1				1		1				3	
Disturbance Prevention									2				
Water Regulation	1				1							1	1
Water Supply					2				5				7
Soil Retention & Formation	1								1				
Nutrient Regulation													
Waste Treatment					3				1				
Pollination	2												
Biological Control													
Refugium Function	1	4			1	4		4	2				
Aesthetic & Recreation	2	12			7	1		12	8			4	17
Cultural& Spiritual	2												

Source: TSS Consulting, 2005

A description of the ecosystems services considered in the estimate of Kern County agro-ecosystem goods and services benefit is provided in Table 4.

[3] The authors were unable to identify additional studies that could be used to augment the Troy and Wilson and TSS Consulting ecosystem services benefit values used in this study.

Table 4: List of Ecosystem Services Included in the Study

Ecosystem Services	Description
Gas and Climate Regulation	Capture and storage of carbon dioxide by forest and other plant cover, reducing global warming
Water Regulation and Supply	Storage, control, and release of water by forests and wetlands, providing local supply of water.
Soil Retention and Formation	Creation of new soils and prevention of erosion, reducing need for dredging and mitigation of damage due to siltation of rivers and streams
Waste Assimilation	Filtering of pathogens and nutrients from runoff by forests and wetlands, reducing the need for water-treatment systems
Nutrient Regulation	Cycling of nutrients, such as nitrogen, through ecosystem for usage by plants, reducing need to apply fertilizers
Habitat Refugium	Benefit of contiguous patches of forest and wetland in supporting a diversity of plant and animal life
Disturbance Prevention	Mitigation of flooding and coastal damage by natural wetlands and floodplains
Pollination	Services provided by natural pollinators such as bees, moths, butterflies, and birds, avoiding need for farmers to import bees for crop pollination
Recreation and Aesthetics	Recreational benefit of natural places as well as positive impact on nearby property benefits

Source: TSS Consulting.

As explained above, this study uses the benefit transfer estimates for ecosystem goods and service by land types generated by Troy and Wilson. These benefits coefficients derived by studies employing a variety of estimation methods were inflated to 2007 US dollar values using the CPI from the Bureau of Labor Statistics. The average benefit estimates by land cover type and ecosystem service are reported in Table 5.

Table 5: Ecosystem Goods and Services Benefit Estimates $/Acre/Year by Land Cover Type and Ecosystem Service

Land Cover	Ecosystem Service	Average Benefit ($/acre/year)
Agricultural Land	Water Regulation	111.57
	Soil Formation	6.35
	Habitat Refugium	13.97
	Pollination	8.98
	Cultural and Spiritual	797.52
	Aesthetic and Recreational	28.08
	Totals	966.46
Forest Conifers	Gas and Climate Regulation (CO2)	32.86
	Habitat Refugium	127.68
	Aesthetic and Recreational	201.56
	Totals	362.10
Fresh Wetland	Water Regulation	503.73
	Waste Treatment	1,853.47
	Habitat Refugium	5.49
	Aesthetic and Recreational	2,475.51
	Totals	4,838.23
Hardwood oak woodland	Gas and Climate Regulation (CO2)	36.87
	Habitat Refugium	127.68
	Aesthetic and Recreational	29.19
	Totals	193.74
Mixed Hardwood Conifer	Gas and Climate Regulation (CO2)	34.86
	Habitat Refugium	127.68
	Aesthetic and Recreational	201.56
	Totals	364.10
Riparian Forest	Water Supply	456.63
	Water Treatment	4.79
	Habitat Refugium	970.03
	Soil Retention	134.20
	Disturbance Prevention	1,073.66
	Aesthetic and Recreational	1,237.22
	Totals	3,876.53
Urban Green	Water Regulation	6.13
	Gas and Climate Regulation	366.48
	Aesthetic and Recreational	2,098.63
	Totals	2,471.24
Open Fresh Water	Water Supply	2,708.11
	Water Regulation	30.02
	Aesthetic and Recreational	452.75
	Totals	3,190.88

The third step in the benefit estimation of Kern County agro-ecosystem goods and services is the formulation of a benefit transfer function. Equation (1) represents the agro-ecosystems goods and services benefit function used in this study, where the total ecosystem goods and services benefit of a given land cover type is calculated by adding up the individual, nonsubstitutable ecosystem goods and service benefits associated with a specific cover type and multiplied by area as follows:

$$V(ESS) = \sum_{i=1}^{13} A(LCT_i) * V(LCT_{k,i}) \quad (1)$$

where
$V(ESS)$ represents the total benefit provided by ecosystem goods and services of the entire area;
$A(LCT_i)$ denotes the area of a specific land cover type, and $i = 1,...,13$ as there are 13 land cover types present in the study area; and
$V(LCT_{k,i})$ represents the annual benefit per unit for ecosystem service type k, associated with land cover type i, with $k = 1,...,13$ to consider the types of the ecosystem services included in the study.

Results

Results of the estimated ecosystem goods and services benefits by land type using equation (1) for Kern County are presented in Table 6.

Table 6: Total Ecosystem Non-Market Goods and Services Benefit Estimates of Ecosystem Services by Land Cover Type

Land Class	Area (Acres)	Ecosystem Benefit ($/Acre/Year)	Total ESV ($)
Agriculture	1,209,465	$966.46	$1,168,899,543.90
Forest-Conifer	176,638	$362.10	$63,960,619.80
Desert Shrub	1,338,701	Unknown	
Desert Woodland	7,141	Unknown	
Fresh Wetland	51,828	$4,838.23	$250,755,784.44
Hardwood Oak Woodland	334,265	$193.74	$64,760,501.10
Herbaceous	1,252,913	Unknown	
Mixed Hardwood Conifer	61,930	$364.10	$22,548,713.00
Riparian Forest	151,005	$3,876.52	$585,373,902.60
Shrubs	381,010	Unknown	
Urban and Barren	2,182,267	Unknown	
Urban Green	94,069	$2,471.24	$232,467,075.56
Open Fresh Water	41,689	$3,190.88	$133,024,596.32
Total Benefit of ESS			$2,521,790,736.72

Results show that ecosystems goods and services provide a relatively large stream of benefits to Kern County, with a total benefit of more than $2.5 billion per year. Agricultural land has a benefit of $966.46 per acre which provides total agro-ecosystem non-market goods and services benefit of $1.2 billion per year or approximately 50% of the estimated benefits from those land types for the ecosystem goods and services benefits that were estimated. This is primarily due to the size of the agricultural land base, relative to the other considered land types. The cultural and spiritual, and water regulation are the most valuable services provided by agricultural land. Riparian forests contribute more than $585 million, mainly through the aesthetic and recreational and disturbance prevention functions. Fresh wetlands provide by far the highest agro-ecosystem services benefit per acre. Even though they cover relatively a small area in Kern County, they do provide the third highest benefit of ecosystem goods and services with a total benefit of more than $250 million per year.

Each of the remaining land type categories contribute to the total benefit of ecosystem goods and services as follows: urban green area provides more than $232 million per year, open freshwater provides about $133 million per year, followed by hardwood and conifers which contribute respectively $64 million and $63 million per year. Desert shrub is the most predominant land cover type in Kern County. However, there are no studies available in the literature that estimate economic benefits for desert cover types and thus their ecosystem services benefit is unknown.

Conclusion

Well-managed agricultural landscapes supply important non-market goods and services to society and this ability and stream of benefits should be explicitly considered in crafting public policies and/or market-based environmental protection and enhancement incentive programs. It can be argued that in order for land-use planners and policy makers to make informed decisions that they need be made aware of the non-market ecosystem services benefits that agricultural lands provide prior to developing land use policies and programs that could have a negative impact on those benefits.

This study illustrates the use of benefit transfer methodology as a tool that can be used to provide land use planners and policy makers' information about the non-market benefits provided by agricultural lands. The benefit transfer methodology used in this study resulted in an estimate of agro-ecosystem goods and services benefit of approximately $1.2 billion or approximately 48% of the total ecosystem goods and services land type benefits in Kern County.

The benefit transfer methodology is admittedly a second-best approach to the estimation of agro-ecosystem services. A basic criticism of benefit transfer methodology is the concern over transfer error, defined as the difference between the transferred value estimate and the true (unknown) value estimate at the policy site. Ready and Navrud (2005) note that several studies find average transfer errors of 40 or 50%, but with a wide range that can span from zero percent to several hundred percent for individual transfer exercises. It can be assumed that this study has a non-zero transfer error. The magnitude of the error for this study is unknown. However, as noted in Loomis et al (2008), several aspects should be considered when determining whether to utilize the BTM or ignore the non-market benefits of a resource. First, that BTM is more accurate than using static benefits such as those that have been developed in the past by government agencies which are adjusted by inflation every year. Second, the range of errors that are associated with benefit transfer can be informative to the decision maker when there is a greater probability of making wrong decision if that decision excludes important non-market benefits. Third, if the choice occasion or policy measure is a multi-million dollar irreversible decision than the errors associated with using transfer benefit may warrant the expense of an original non-market valuation study.

A further constraint to the practical use of benefit transfer methods for assessing ecosystem benefit is the lack of GIS and/or economic expertise among public land use planners. A promising approach to the solution to this constraint is presented by Loomis, et al (2008). Loomis et al present a benefit transfer toolkit that contains that contains the need databases, average benefit tables, meta analysis-based pre-programmed spreadsheets that are necessary to estimate ecosystem goods and service benefits. They illustrate the use of the toolkit valuing non-wildlife recreation such as hiking, camping, and reservoir recreation as well as natural environments such as wilderness. It may be possible to develop a similar toolkit so that it can be used by appropriate land-use planners to evaluate the agro-ecosystem benefit of agricultural lands.

As noted earlier a valid argument for the adoption and use of transfer benefit is the needs and demands of policy makers and natural resource managers for estimates of non-market environmental benefits concomitant with time and resource scarcity. The time and money constraints faced by those policy makers and natural resource managers provides support for utilizing benefit transfer methodology when assessing the agro-ecosystem non-market goods and services that agricultural lands provide to society. It can be a useful method for explicitly considering agricultural land non-market agro-ecosystem non-market goods and services when crafting public policies and/or market-based incentive programs.

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