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Effects of wildfire on national park visitation and the regional economy: a natural experiment in the Northern Rockies

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Abstract. Federal wildland fire management policy in the United States directs the use of value-based methods to guide priorities. However, the economic literature on the effect of wildland fire on nonmarket uses, such as recreation, is limited. This paper introduces a new approach to measuring the effect of wildfire on recreational use by utilising newly available long-term datasets on the location and size of wildland fire in the United States and observed behaviour over time as revealed through comprehensive National Park Service (NPS) visitor data. We estimate travel cost economic demand models that can be aggregated at the site-landscape level for Yellowstone National Park (YNP). The marginal recreation benefit per acre of fire avoided in, or proximate to, the park is US$43.82 per acre (US$108.29 per hectare) and the net present value loss for the 1986–2011 period is estimated to be US$206 million. We also estimate marginal regional economic impacts at US$36.69 per acre (US$90.66 per hectare) and US$159 million based on foregone non-resident spending in the 17-county Great Yellowstone Area (GYA). These methods are applicable where time-series recreation data exist, such as for other parks and ecosystems represented in the 397-unit NPS system.

Additional keywords: benefit–cost, non-market values, recreation, wildfire economics.

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Introduction

Wildland fire not only affects resources for which market prices exist, such as private homes, but also nonmarket uses including recreation. In the United States, the current policy guidance (FEC 2009) is for consideration of both long-term costs and benefits in fire analysis. The recommended decision-support tool is now the Wildland Fire Decision Support System (WFDSS). These price-based approaches to wildland fire management require knowing resource value changes due to fire. However, a recent paper by Venn and Calkin (2011) reviews the available literature on non-market resources affected by fire and identifies several major challenges to evaluating welfare changes arising from large-scale disturbances to the natural environment. Specifically in the context of wildfire, the challenges include insufficient scientific information to assess how non-market forest goods and services are affected by wildfire and a dearth of studies that have estimated marginal willingness to pay (WTP) to conserve non-market forest goods and services. Other challenges include the limited amenability of many non-market forest goods and services to valuation by benefit transfer[A] and violation of consumer budget constraints by some widely used stated preference approaches.[B]

This paper contributes to the literature on the effect of wildfire on recreation by introducing a new approach that uses newly available long-term datasets on wildland fire size and location in the United States, along with comprehensive visitation datasets maintained by the National Park Service (NPS). These datasets taken together amount to a natural experiment where the response to wildland fire can be observed over time. Our primary working hypothesis is that there are significant and predictable concurrent effects of wildland fire on recreation and that these effects may operate at the landscape level. We

[A]Benefit transfer attempts to apply previous estimates of WTP for another service or for another site (e.g. the study site) at an unstudied ‘policy site’ (e.g. the current site). Economists are divided over the validity of benefit transfer (Boyle and Bergstrom 1992; Spash and Vatn 2006).

[B]The concern is that stated preference studies that, for example, ask for household WTP to conserve a specific species (such as the spotted owl) when added up over many important endangered species may exceed the budget consumers have available for conservation.

demonstrate these methods with an application to Yellowstone National Park (YNP), which is located in the northern Rockies – an area including the states of Montana, Idaho and Wyoming.

Prior research on wildland fire effects on recreation has focussed on the response of recreationists to onsite fire-related changes in the post-fire landscape. This literature is primarily based on surveys of backcountry users (such as hikers and bikers) using trails in the national forests. This line of research had its beginning with a study by Vaux *et al.* (1984) that demonstrated the use of stated preference methods (specifically contingent valuation) on a convenience sample of students. Vaux *et al.*'s specific approach included the use of photos of forests in various states of recovery from fire and came to the general conclusion that fires have a negative effect on recreation values. This general finding of a negative effect soon after a fire was also supported by revealed preference approaches by Englin *et al.* (1996), using observed behaviour of backcountry canoe recreationists in Nopiming Park, Manitoba. More recent papers (Englin *et al.* 2001; Loomis, *et al.* 2001; Hesseln *et al.* 2003) continue the use of photos and contingent valuation responses, but in models that combine stated preference with travel cost methods. These authors utilise trip frequencies as the response to changes in forest conditions resulting from wildland fire. A finding from this research is that trip frequencies and recreation values following fire are non-linear. The actual variation across sites in fire history (presence, absence of fire, size of fire, years since fire occurred) is supplemented by respondents' stated preferences for more or less trips, usually in response to photos of typical forest scenes. Hesseln *et al.* (2003) found that hikers and bikers in New Mexico experience decreases in consumer surplus following either crown or prescribed fire from the year of the fire to 40 years post-fire.

A recent pooled revealed preference-stated preference study (Boxall and Englin 2008) uses changes in recreation site choice (rather than trip frequency) in a random utility model (RUM) framework. A finding of this study is that marginal per-trip welfare declines immediately after a fire, but recovers on a non-linear path after ~35 years of regrowth. Another recent paper in this area of research also applied a RUM model to track post-fire welfare effects (Englin *et al.* 2006). An interesting finding is that there is considerable heterogeneity in visitors' preferences for ancient (fire affected) forest ecosystems. Hilger and Englin (2009) introduced the application of an incomplete demand system approach to the modelling of wildland fire effects on recreation.

Hesseln *et al.*'s (2004) study of hikers and bikers at 22 sites within four national forests in Montana is, to our knowledge, the only previous quantitative study of wildfire effects on recreation in our study area. Contrary to the New Mexico findings, Montana hiker and biker welfare was not significantly affected by the type of fire (crown or prescribed), but was affected by the size of the fire and the number of years of recovery since the fire. For example, at 40 years after a crown fire, hiker visitation was estimated to drop from 14.0 trips per year to 13.4 trips per years. The authors conclude that 'the absolute change in demand, although statistically significant, is small enough to be inconsequential from a managerial perspective' (Hesseln *et al.* 2004, p. 52). Hesseln *et al.* (2004) also note that it was not possible to randomly sample sites due to the limited number of recreation trails that were burned by either wildfire or prescribed fire, and that the results may not be representative of use on all national forest in Montana. Accordingly, the authors do not report any aggregate results, which is also typical of this literature.

In another wildfire-related study in Montana, Love and Watson (1992) examined the post-fire effects of the Gates Park fire of 1988, which burned 21 044 ha along the North Fork of the Sun River in the Bob Marshall Wilderness. Visitors were interviewed in the summer and fall (autumn) of 1989, along the North Fork and along the unburned South Fork of the Sun River. The authors concluded that the Gates Park fire had relatively little effect on the choice to visit the North Fork or the South Fork, or on visitor satisfaction, and that the tendency of wilderness visitors was to look at the fire as a component of the natural environment. The findings of Love and Watson (1992) are generally qualitatively consistent with Hesseln *et al.*'s (2004) finding that post-fire changes in the backcountry landscape had only small and inconsequential effects on visitor use.

This study utilises an input–output modelling structure to estimate the total regional economic impacts of changes in YNP visitor spending on the local area economy. The literature on input–output modelling began with the work of Leontief (1941) who utilised a system of linear equations that demonstrate the interdependence of industries (Miller and Blair 2009). Modern input–output models are commonly used to model the effect an initial change in final demand in one or a set of economic sectors would have on the wider set of all economic sectors within a predefined local, state or regional economic area. There is a substantial literature of studies applying input–output modelling to recreational spending. Bergstrom *et al.* (1990) used an early version of the IMPLAN model (for example, MIG 2010) to estimate the effect of spending by visitors to state parks in the southern United States. More recently Munn *et al.* (2010) utilised the IMPLAN model in conjunction with estimated spending from the USFWS 2006 survey of fishing, hunting and wildlife-associated recreation to estimate the significance of this spending to the economy of the south-eastern United States. Regional input–output model analysis has also been used to assess the effects of changes in recreational spending by visitors to high-profile national parks. The regional economic impacts of the damage to Yosemite National Park, and associated park closure, after flooding in 1997 were estimated using the IMPLAN modelling structure (Neher and Duffield 2000). In YNP, Duffield *et al.* (2008) estimated the regional economic impact of changes in visitor expenditures due to the presence of wolves in the park ecosystem.

In summary, previous research on effects of wildfire on recreation has used survey research on post-fire effects at the local site level, and generally is based at least in part on stated preference methods. An alternative approach to modelling the effect of wildland fire on recreation is to compare observed aggregate visitation at a site or sites in a time series model to the actual historical pattern of fires on or proximate to the site. This approach is appealing in part because it is based entirely on revealed preference observed behaviour approaches. Until the last several years, this approach would have entailed considerable work in creating the relevant fire history dataset. Fortunately, the National Wildfire Coordinating Group (NWCG), which includes all the major federal land management agencies

Table 1. Fire activity-visitation model variable definitions
YNP, Yellowstone National Park; GNP, Glacier National Park

Variable	Description
Dependent variables	
YNPTRIPS	Monthly recreational visitation to YNP
YNPANNUALTRIPS	Annual recreational visitation to YNP
YNPBACKTRIPS	Annual Yellowstone backcountry trips
Fire variables	
YNPFIRE50	Acres burned within 50 miles (~80.5 km) of YNP during the month
YNPFIRE100	Acres burned within 100 miles (~160.9 km) of YNP during the month
YNPFIRE200	Acres burned within 100 miles (~160.9 km) of YNP during the month
YNPANNUALFIRE	Acres burned within YNP during the year
GNPFIRE50	Acres burned within 50 miles (~80.5 km) of GNP during the month
Lag fire variables	
LAGYNPFIRE50	Acres burned within 50 miles (~80.5 km) of YNP during the previous data month
LAGYNPFIRE100	Acres burned within 100 miles (~160.9 km) of YNP during the previous data month
LAGYNPFIRE200	Acres burned within 100 miles (~160.9 km) of YNP during the previous data month
LAGYNPANNUALFIRE	Acres burned within YNP during the previous year
Indicator and trend variables	
MAY–SEPTEMBER	Indicator variables (1 or 0) for May, June, July, August and September
TREND	Annual trend variable
Economic variable	
PRICEINCOME	Real gasoline price ÷ real per capita personal income

as well as some state agencies, maintains a website (www.nwcg.gov, accessed 14 March 2012) that includes electronic records for the major US fire reporting system (Situation Report/Incident Status Summary (SIT/209)). This fire dataset could be used with any aggregate time series visitation dataset. Our study site, Yellowstone National Park, is a major destination and a primary driver of the Montana tourism sector (Wilton and Nickerson 2006), which is second only to agriculture and mining in importance to the state's regional economy. In this paper we estimate marginal benefit functions for wildland fire effects on recreation for both a benefit–cost (willingness to pay, WTP) accounting framework and a regional economic (input-output model) framework.

Methodology

This study utilised existing time series data on US fire activity combined with NPS recreational visitation data to estimate linear regression models of park visitation (specifically YNP) as a function of wildfire activity within or proximate to the park. Additionally, two alternative models of YNP visitor WTP per trip were estimated from existing data. First, an estimate of YNP visitor WTP was estimated from the economic variable coefficients within the fire-visitation model. A second count data travel cost model of YNP visitor WTP was estimated based on survey data collected in 2005–2006 from YNP recreational visitors.

The results of the fire-visitation models and the visitor WTP estimates were used to derive estimates of the total economic impacts of wildfire activity within or proximate to YNP on local area visitor spending and on park visitor WTP. Also included are estimates of the marginal economic benefits per acre of fire avoidance proximate to YNP.

Fire-visitation effects models

The unique nature of the combined fire activity and park visitation data allowed for specification of a time-series travel cost model regressing park visitation on fire activity, a set of month indicator variables and economic variables. The travel cost model views visitor travel cost as a spatially varying price that drives demand at a site (Champ *et al.* 2003). Several models were estimated for YNP exploring various functional forms, and specification and aggregation of the fire activity variables. Models were estimated both on monthly fire and visitation data, and on annual data. The general specification of the fire-visitation models for park *j* and time *t* was a linear regression model:

$$Visitation_{j,t} = f\left(\begin{matrix} Firevariables_{j,t}, Firevariables_{j,t-1}, \\ EconomicVariables_{j,t}, Trendvariable_{j,t}, MonthIndicators_{j,t} \end{matrix}\right) + e_{j,t} \qquad (1)$$

Table 1 shows the variable names and definitions of the full set of variables used in the fire-visitation modelling. Economic variables include the key price and income variables that follow from economic demand theory (Varian 1992). This specification is essentially equivalent to the aggregate '2nd stage demand curve' in a zonal travel cost model (Champ *et al.* 2003). Our specification of these variables (price ÷ income) is theoretically consistent with utility maximising behaviour. We utilise gasoline (petrol) prices (in constant dollar terms) as a sample-wide price index for travel costs, because a change in gas prices results in a proportional change in variable travel costs at all distances. This approach is conservative because other costs (such as lodging and food) are also likely to change with travel distance.

Hypothesis tests

Prior research has focussed on recreational response to post-fire effects and recovery. This study differs in that we also investigate concurrent effects and effects for fires not only at the site, but proximate. For example, does news of a major fire burning in the vicinity of YNP influence decisions to visit that park? An empirical issue is how far distant can fires be and still influence recreationists' decision making. We are also interested in the lagged inter-temporal effect of previous fires on current use. Previous research, using in part intended behaviour response to photos depicting stages of forest recovery, identified lagged effects of up to 60 years. We are curious to see if this is supported by aggregate time series data. We also investigate, in a limited way, cross-site substitution effects at two sites, Glacier National Park (GNP) and YNP. Estimated coefficients and standard errors for key explanatory variables in the fire-visitation models were used to assess the size and statistical significance of the effect of fire activity and economic conditions on park visitation. Hypothesis tests were evaluated through the use of *t*-test statistics for the estimated coefficients. Hypothesis tests specifically examined in this study are shown in Eqns 2–5.

$$\begin{gathered} H_0 = \beta_1 \ (\textit{Fire variables}) = 0 \\ v. \\ H_a = \beta_1 \ (\textit{Fire variables}) \neq 0 \end{gathered} \tag{2}$$

$$\begin{gathered} H_0 = \beta_2 \ (\textit{LAG Fire variables}) = 0 \\ v. \\ H_a = \beta_2 \ (\textit{LAG Fire variables}) \neq 0 \end{gathered} \tag{3}$$

$$\begin{gathered} H_0 = \beta_3 \ (\textit{Cross Site Fire variables}) = 0 \\ v. \\ H_a = \beta_3 \ (\textit{Cross Site Fire variables}) \neq 0 \end{gathered} \tag{4}$$

$$\begin{gathered} H_0 = \beta_4 \ (\textit{Economic variables}) = 0 \\ v. \\ H_a = \beta_4 \ (\textit{Economic variables}) \neq 0 \end{gathered} \tag{5}$$

US wildfire activity data

Extensive historical data on US wildfire activity since the early 1900s are available on the National Fire and Aviation Management Web Application website.[C] Data compiled from wildfire Situation Reports for the entire period are available for download from this site. Fire data for 1986–2011 were utilised in this analysis because the fire data reported before 1986 were too sparse for our purposes . The fire data used were for 13 states in the western USA and included key variables for each fire's point of origin (expressed in latitude and longitude), the final size of the fire in acres (also expressed in hectares), and the start date of the fire. There were 185 503 fires in this dataset for the 1986–2011 period; we used 11 579 fires over 10 acres (4.05 ha) in size for the May–October fire season. The location coordinates for the fires were used to calculate distance between the fire origins and the centre of YNP. The key variables of fire size, date and distance from the park for the 11 579 individual fires were used to aggregate fire activity to the month level and calculate a range of fire activity measures by month. Fig. 1 shows a partial plotting of the fire data for the states of Montana, Idaho and Wyoming and for a subset of the data years (1999–2009), as well as the location of the study site. Fire variables examined included acres burned within various radii of the park centre such as within 50, 100 or 200 miles (~80.5, ~160.9 or ~321.9 km).

National Park Service visitation statistics data

The NPS maintains comprehensive historical data on visitation to all NPS units (NPS 2012).[D] Although the exact nature of the detailed data reported varies somewhat depending on the setting and type of park unit, all parks report data on monthly recreational visitation. NPS units differ from national forests in that there are entry stations and fees at a limited number of entry points. Accordingly, unlike prior research based on survey samples, the visitation data for our application essentially amounts to a census of users. Monthly park visitation data were downloaded for YNP for the period corresponding with the wildfire data (1986–2011).

Additionally, data on YNP backcountry and other camping activity were also accessed from the NPS data website. These data identified a subset of YNP visitors (backcountry users and campers) who, while making up a small share of total visitation (~2%), are likely the most directly affected by fire activity within the park.

Yellowstone National Park fire data

YNP maintains a database of fire activity located exclusively within park boundaries. These data are available for the period 1972–2009.[E] The YNP data are annual data showing the total YNP acres burned during the year by fires that either began within, or burned into the park. This time series is of interest because (like our monthly data) it is long enough to include the year 1988, in which nearly 800 000 acres (~323 750 ha) of YNP burned.

Yellowstone National Park visitor survey

We utilise two sources of data to measure the effect of wildfire on recreational resource use and values. Monthly fire and visitation data support an estimate of the marginal effect of wildland fire on recreational visits. We also utilise a second dataset of park visitor survey data that provides estimates of YNP visitor expenditures and park visitor trip WTP.

Original data were gathered from a random survey of YNP visitors between December 2004 and February 2006 (Duffield *et al.* 2006). Throughout the sampling period a total of 2992 surveys were distributed and 1943 were completed and returned for an overall response rate of 66.4%. The YNP survey, which asked questions on visitor expenditures, demographics, opinions, and visitation and travel patterns, utilised a handout-mailback contact format with multiple recipient contacts

[C] Databases of all fire activity reported from US Situation Reports for the years 1986–2011 were downloaded from http://fam.nwcg.gov/fam-web/ (accessed 20 February 2012).

[D] Recreational visitation data were downloaded from the NPS-maintained site: http://www.nature.nps.gov/stats/ (accessed 18 February 2012).

[E] Data on Yellowstone National Park (YNP) annual fire activity for the years 1972–2009 were maintained by YNP and were supplied by Roy Renkin of YNP.

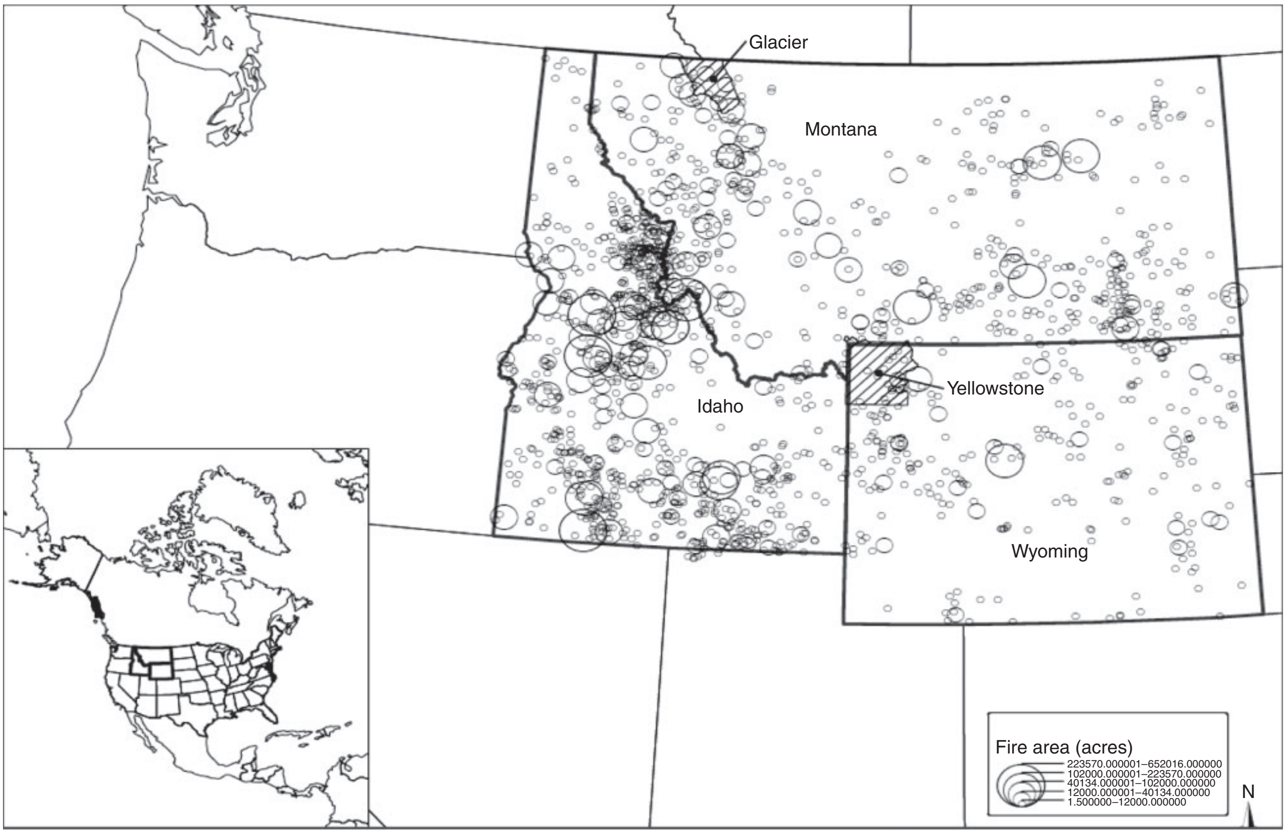

Fig. 1. Plot of fire activity in Montana, Idaho and Wyoming: 1999–2009. (Source: Situation Report data).

following a Dillman (2000) protocol. The survey also included analysis for potential non-response bias. The survey packets were distributed by YNP staff at park entrance stations following a yearlong stratified random sampling plan design. While the year-long survey data were aggregated for WTP modelling purposes, the estimated model of WTP was used to develop estimates for each of the park's four seasons, estimates specific to the summer visitation season (June–September), which coincides with most of observed fire activity, were used in this application. The response rate for summer season visitors was 63.1% and the summer visitor responses constituted 33.7% of the total year-long sample.

Park visitor WTP models

The estimated fire-visitation models provide estimates of the effect on park visitation associated with one additional acre within or proximate to the park being burned. Thus the estimated coefficients on acres burned in the current (or previous) month can be used to estimate the effect of past or future fires on the number of recreational visitors to YNP. Park visitors provide local area economic stimulus though their spending in the park area. Estimates of park visitor spending for YNP were derived from the YNP visitor survey.

An additional economic impact of park visitation is the WTP for visitors associated with their park visit. WTP is the value over and above what a park visitor must spend on their trip that the visitor derives from their park visit. Willingness to pay per visit to YNP was estimated both with the time-series fire-visitation travel cost model for YNP and with a conventional count data travel cost model based on the YNP visitor survey.

Consumer surplus estimated from Yellowstone annual fire visitation model

The fire-visitation models include the economic variable PRICEINCOME, which is the real average price of gasoline divided by real per capita personal income. This model was used to derive a travel cost estimate of visitor consumer surplus based on changes in visitation levels (all else being constant) associated with rising and falling gas prices.

Derivation of estimated consumer surplus per visit involved using the estimated fire-visitation model coefficients to calculate the gasoline price at which visitation is predicted to equal zero and to predict what the visitation level would be at a gasoline price of zero. Additionally, estimated numbers of persons per vehicle, average miles travelled per visitor vehicle and average miles per gallon fuel efficiency were used to calculate average consumer surplus per trip (Eqn 6). The average consumer surplus per visitor trip can be expressed as:

$$CS = \frac{gas\ price_{zero\ visits} \times Visits_{zero\ gas\ price}}{2 \times persons\ per\ vehicle} \times \frac{1}{Average\ visitation} \times \frac{Miles\ travelled}{miles\ per\ gallon} \tag{6}$$

Consumer surplus estimated from cross-sectional Yellowstone National Park visitor data

The second complimentary method used in this analysis for estimating the value of a visitor trip to YNP is a variant of the individual observation travel cost model. This model explains the number of trips an individual has taken to a park during the previous 12 months as a function of the cost (and by proxy, the distance) associated with making the trips to the park from their home.

We follow the standard approach for estimating the individual travel cost model (e.g. Shaw 1988; Hellerstein and Mendelsohn 1993; Englin and Shonkwiler 1995; Cameron and Trivedi 1998). The standard individual observation travel cost model is defined as

$$Trips_i = f(s_i;\beta) + e_i \tag{7}$$

where $Trips_i$ is the number of observed trips that the ith visitor would take to the national park in a specific time period; s_i is the vector of explanatory variables for the ith visitor including travel costs to the site, income, age, type of trip, group size, travel costs to substitute sites, etc.; β is a vector of unknown parameters; and e_i is the error term. The most widely applied models for count data are the Poisson regression model and negative binomial regression model (Cameron and Trivedi 1998). Englin and Shonkwiler (1995) derived a negative binomial model that simultaneously corrects for three primary problems associated with onsite count data analysis: over-dispersion relative to the Poisson; truncation at zero of the dependent 'trips' variable; and endogenous stratification due to oversampling of frequent visitors to the site. The Englin and Shonkwiler specification was used in this analysis. The per-visit WTP can be directly estimated from the estimated coefficients of the travel cost count data models. Specifically, consumer surplus per visitor trip is calculated as

$$\frac{CS}{Trip} = \left(-\frac{1}{\beta_{Trip\,cost}}\right) \tag{8}$$

Economic impacts

This analysis utilised the IMPLAN input–output modelling program (MIG 2010) and IMPLAN data for the 17-county Greater Yellowstone Area (GYA) to model the effects to local area earnings and employment from changes in YNP visitor final demand. Regional economic impact models are input–output models that include several assumptions: constant returns to scale; unconstrained supply; fixed commodity input structure; and homogenous sector outputs. The input–output model employed in this analysis, IMPLAN, is used to model the total effect on the economy resulting from direct changes in YNP visitor direct spending in the local economy. The IMPLAN input–output model uses changes in final demand to estimate direct, indirect and induced effects of changes in final demand. The vector of final demands (Y) for products (or services) in each of the IMPLAN sectors (1 to n) is calculated using matrix notation as:

$$X - AX = Y \tag{9}$$

where X is a vector of outputs for each sector (1 to n) in the model and A is a matrix of technical coefficients. Changes in employment and income in the defined economic area are derived from a given change in final demand as,

$$X = (I - A)^{-1}Y \tag{10}$$

where I is an identity matrix. Effects on employment and income derived from the model based on an initial change in final demand include direct effects in the final demand sector affected, indirect effects for businesses linked to the final demand sector affected through input purchases, and induced effects from expenditures of income generated in the directly and indirectly affected sectors.

Results

The current study included the estimation of a range of regression models. Table 1 outlines the variables used in the fire activity-visitation models and their definitions. Linear specifications of the estimated models are presented. Alternative specifications (semi-log and log-log) did not improve the fit of the models, so the linear specification was used.

Monthly fire-visitation models

Monthly fire-visitation models for Yellowstone National Park

Estimated monthly fire-visitation models for YNP are shown in Table 2. The data for these models included all reported fire activity data within the months May through October, for the years 1986–2011. Table 2 shows a set of models regressing monthly YNP visitation on various specifications of fire activity, indicator and economic variables. All models in Table 2 are highly explanatory ($R^2 > 0.95$) and all explanatory variables in the models are significant at the 0.05 level or greater. Variable means and standard deviations for the monthly fire data models are shown in Table 3.

Models A–C include only the month-specific fire-activity variables, whereas models D–F also include lagged specifications of the variables for the previous dataset month. All estimated coefficients in models A–F are significant at the 0.05 level or greater and have the expected negative sign, indicating the fire activity near YNP reduces recreational visits to the park. Model G includes fire activity within 50 miles (~80.5 km) of GNP (the other high-profile National Park unit within the three-state region) as an additional explanatory variable. The significant negative coefficient on the GNPFIRE50 variable indicates that visiting GNP is often a complement to visiting YNP, and fire activity near GNP reduces visitation to YNP.

Yellowstone National Park annual fire-visitation models

On an *a priori* basis it was expected that significant fire activity within YNP, all other things equal, would be correlated with decreased recreational visitation to the park. Fires lead to road and campground closures, create smoke and significantly change the landscape within the park. Four specific models of annual visitation to YNP are reported in Table 4: full and reduced models of total recreational visitation; and full and reduced models of backcountry visitation. The full model

Table 2. Yellowstone visitation models: monthly May–October 1986–2011 fire data
Probabilities are significant at: *, 90%; **, 95%; ***, 99%

Model	Current monthly specification			Lag specification			Substitutes and complements specification
	A	B	C	D	E	F	G
Intercept	213 188***	214 028***	215 181***	207 863***	210 178***	212 709***	213 764***
(s.e.)	(17 768)	(17 628)	(17 474)	(16 654)	(16 488)	(16 158)	(17 665)
YNPFIRE50	−0.091***			−0.06836**			−0.09278***
	(0.03113)			(0.2945)			(0.03095)
LAGYNPFIRE50				−0.14059***			
				(0.2944)			
YNPFIRE100		−0.09898***			−0.07208**		
		(0.0304)			(0.02891)		
LAGYNPFIRE100					−0.13930***		
					(0.0289)		
YNPFIRE200			−0.10448***			−0.06949**	
			(0.02883)			(0.02745)	
LAGYNPFIRE200						−0.14254***	
						(0.02745)	
GNPFIRE50							−0.62846*
							(0.37683)
MAY	73 757***	73 678***	73 593***	75 711***	75 509***	75 198***	73 743***
	(15 252)	(15 152)	(15 032)	(14 394)	(14 281)	(14 015)	(15 161)
JUNE	407 515***	407 841***	407 851***	407 556***	407 566***	407 204***	407 506***
	(15 255)	(15 156)	(15 036)	(14 251)	(14 141)	(13 877)	(15 164)
JULY	653 624***	654 536***	658 005***	652 692***	653 520***	655 160***	657 453***
	(15 417)	(15 324)	(15 333)	(14 404)	(14 299)	(14 161)	(15 496)
AUGUST	556 467***	558 032***	560 095***	566 418***	567 793***	573 202***	559 209***
	(15 256)	(15 173)	(15 089)	(14 403)	(14 300)	(14 151)	(15 254)
SEPTEMBER	275 773***	275 822***	275 950***	277 587***	279 568***	282 144***	277 021***
	(15 251)	(15 150)	(15 031)	(14 252)	(14 156)	(13 923)	(15 178)
PRICEINCOME	−646 714 101***	−653 417 597***	−662 861 414***	−600 546 937***	−618 622 211***	−637 761 766***	−651 683 186***
	(122 057 677)	(121 014 187)	(119 895 792)	(114 636 555)	(111 017 884)	(111 017 884)	(121 366 235)
Sample size	156	156	156	155	155	155	156
R^2	0.952	0.952	0.953	0.958	0.959	0.96	0.953

specifications include a lagged YNP acres burned variable specific to fire activity in the preceding year. Fire activity variables examined to further explore inter-temporal effects, but not reported in Table 4, included higher order lags for 2, 3 and 4 years. Table 5 shows variable means and standard deviations for the YNP annual visitation model variables.

Both reduced models show significant estimated coefficients for the fire activity variable (YNPANNUALFIRE). Additionally, the estimated coefficients are of the expected signs (–) indicating that increased fire activity within the park is associated with decreased visitation levels. A comparison between the two models of annual visitation shows another expected result. The elasticity at the mean for the fire coefficient is 2.7 times larger in the model of backcountry use than it is in the model of total park visitation. That is, on a percentage change basis, backcountry park visitors are more sensitive to fire activity within the park than are visitors to the park as a whole with respect to inter-temporal effects. Neither of the models that included lagged fire activity variables (in addition to the same-year fire variable reported above) resulted in statistically significant estimated coefficients for any specification of the lagged terms.

Table 3. Variable means: monthly May–October 1986–2011 fire data

Variable	*n*	Mean	s.d.
YNP Monthly Visitation	156	466 150.34	244 723.84
YNPFIRE50	156	14 863.69	144 856.48
YNPFIRE100	156	19 082.89	147 191.10
YNPFIRE200	156	27 754.31	155 955.84
TREND	156	12.5	7.52
MAY	156	0.17	0.37
JUNE	156	0.17	0.37
JULY	156	0.17	0.37
AUG	156	0.17	0.37
SEPT	156	0.17	0.37
PRICEINCOME	156	0.0001137	3.634E–05
GNPFIRE50	156	2037.74	11 893.85
LAGYNPFIRE50	155	14 959.59	145 321.07
LAGYNPFIRE100	155	19 206.00	147 660.16
LAGYNPFIRE200	155	27 932.65	156 445.41

Table 5. Variable means, Yellowstone National Park annual model of visitation and within-park fire activity

Variable	*n*	Mean	s.d.
Non-lagged models of total visitation			
YNPVISITS	38	2 664 014	395 846
GNPVISITS	38	1 785 711	232 134
YNPBURN	38	25 190	128 286
PRICEINCOME	38	0.0000616	0.0000151
TREND	38	18.5	11.11
Lagged models of total monthly visitation			
YNPVISITS	37	2 675 557.68	394 768.38
GNPVISITS	37	1 796 370.46	225 710.26
YNPBURN	37	25 870.38	129 985.84
LAGBURN	37	25 576.51	130 032.96
LAGLBURN	37	5.28	3.79
PRICEINCOME	37	0	0
TREND	37	19	10.82
Models of monthly backcountry visitation			
YNPBACK	31	51 806.81	8 473.21
YNPBURN	31	30 775.32	141 852.69
LAGBURN	31	30 424.90	141 916.88
LAGLBURN	31	5.43	4
PRICEINCOME	31	0	0
TREND	31	22	9.09

Table 4. Estimated models of Yellowstone National Park annual visitation and wildfire activity (Total annual visitation model is for 1972–2009; Backcountry visitation model is for 1979–2009)

Probabilities are significant at: *, 90%; **, 95%; ***, 99%; n.s., not significant

Coefficient or statistic	Total annual visitation		Backcountry visitation	
	Linear specification		Linear specification	
	Full model	Reduced model	Full model	Reduced model
Intercept	2 660 641***	2 655 090***	52 650***	50 357***
(s.e.)	(205 980)	(190 818)	(9204.99)	(9146.30)
YNPANNUALFIRE	−0.62207**	−0.619**	−0.02725**	−0.0263**
	(0.26675)	(0.25827)	(0.01002)	(0.01011)
LAGYNPANNUALFIRE	−0.06598		−0.01287	
	(0.26562)		(0.00993)	
PRICEINCOME	−71 289 778***	−70 757 588***	−448 135	−268 789
	(25 786 432)	(24 532 836)	(1 009 495)	(1 012 463)
TREND	24 844***	24 875***	141.3	176.8
	(3625.81)	(3324.46)	(183.50)	(183.71)
Sample size	37	38	31	31
R^2	0.76	0.77	0.3	0.26
Elasticities at means				
YNPANNUALFIRE	−0.00602	−0.00585	−0.01619	−0.01562
LAGYNPANNUALFIRE	n.s.	–	n.s.	–

Table 6. Yellowstone National Park study data, variable definitions and descriptive statistics

Parameter	Description	*n*	Mean	s.d.
TRIPS	Trips to YNP in previous 12 months (including current trip) × group size	928	4.9449	10.315
TRAVEL COST	(Round trip miles × mileage rate) + YNP entry fee	928	213.27	182.83
INCOME	log(household income)	928	8.423	4.018
AGE	Age of respondent	924	49.84	15.9
FAMILY	FAMILY = 1 if group is travelling with family; 0 if not	298	0.723	0.448
MULTI DAY	MULTIDAY = 1 if trip > 1 day; 0 if not	293	0.741	0.438
SUMMER	SUMMER = 1 if month is June, July or August; 0 if not	298	0.381	0.486
FALL	FALL = 1 if month is September, October or November; 0 if not	928	0.242	0.429
SUMMER × TC	SUMMER × TRAVELCOST	928	77.65	142.42
FALL × TC	FALL × TRAVELCOST	928	53.47	134.58
MAINDEST	MAINDEST = 1 if YNP was the main destination on the trip; 0 if not	928	0.505	0.5
MAINDEST × TC	MAINDEST × TRAVELCOST	928	90.86	154.45

Yellowstone National Park visitor consumer surplus models

Average consumer surplus, or WTP per trip, for YNP visitors was estimated using two approaches and datasets. Using the YNP annual fire-visitation dataset and Eqn 6, an average WTP per YNP recreational visit was estimated to be US$136.00.

A second estimate of average summer month YNP WTP was based on 2005 YNP visitor data. Using data on number of visits to YNP in the previous 12 months and distance travelled to the park, along with other seasonal and visitor characteristic covariates (Table 6), the individual observation travel cost model of YNP visitation (Table 7) estimates the WTP associated with one summer season visit to YNP is US $175.00 (Eqns 7–8). In the following analysis of economic impacts of YNP fire activity, we use the more conservative estimate of US$136.00 per YNP visit from the YNP annual fire-visitation model results (Eqn 6).

Economic benefits of fire avoidance

The results of the explanatory models of both monthly YNP visitation and fire activity, and annual YNP visitation and acres burned within the boundaries of YNP show a clear, consistent relationship between acres burned either within or proximate to the park and number of visitors to the park. Economic impacts of fire activity associated with reduced visitation to YNP are estimated for both reductions in visitor spending in the 17-county GYA, and reductions in visitor WTP associated with fewer trips taken (Table 8).

Over the period 1986–2011 monthly fire activity within 200 miles (~321.9 km) of YNP varied dramatically. In May–October 1993 only 35 acres (~14.1 ha) were reported burned within 200 miles of YNP; in May–October 1988 over 2.3×10^6 acres (~9.3×10^5 ha) burned within 200 miles of YNP. Over the 26 years of fire data, an average of 166 526 acres (~67 390 ha) burned within 200 miles of YNP annually in May–October. The median area burned for the same period was 21 295 acres (~8617.7 ha). Based on direct expenditures within the 17-county GYA per out of area visitor of US$187.85, it is estimated that in an average fire year direct YNP visitor spending is US$6.1 million less than would occur without any fire activity. Over the 26-year period of data, the cumulative non-discounted local area reduction in visitor spending due to fire activity within 200 miles of YNP is estimated to be in the range of US$159 million.

Table 7. Yellowstone National Park study data, estimated travel cost model of willingness to pay

Probabilities are significant at: *, 90%; **, 95%; ***, 99%

Zero-truncated negative binomial with endogenous stratification model Parameter	Estimate	s.e.
CONSTANT	1.2972***	0.3676
TRAVEL COST	−0.0101***	0.00071
INCOME	0.0296***	0.01031
AGE	−0.0007	0.00319
FAMILY	−0.3767***	0.08667
MULTI DAY	−0.2418***	0.08935
SUMMER	−0.6700***	0.1285
FALL	−0.8157***	0.1501
SUMMER × TC	0.0030***	0.00071
FALL × TC	0.0024***	0.00081
MAINDEST	−0.1189	0.1241
MAINDEST × TC	0.0028***	0.00065
ALPHA	4.4530***	1.6157
Sample	919	
WTP calculations from parameter estimates Season and status of destination	**WTP per person trip (US$)**	
Yellowstone was primary destination		
Spring	136.97	
Summer	231.96	
Fall	204.16	
Yellowstone was a secondary destination		
Spring	99.30	
Summer	141.24	
Fall	130.43	
Average Summer Visitor	175.00	

Losses in direct visitor expenditures are related to even greater reductions in total local area economic output due to the multiplier effects of local expenditures. Based on IMPLAN regional economic data and modelling for the 17-county GYA, the expenditure multiplier (direct, indirect and induced) for the area is estimated to be 1.6 (IMPLAN System (data and software); MIG Inc.; see http://www.implan.com, accessed 19 April 2010).

Table 8. Marginal effects of proximate fires (1986–2011) on visitor benefits and expenditures, Yellowstone National Park and the 17-county Greater Yellowstone Area

YNP, Yellowstone national Park; WTP, willingness to pay

Statistic	Average fire year 1986–2011	Median fire year 1986–2011
Acres burned within 200 miles (~321.9 km) of YNP	166 526	21 295
Sum of fire acres coefficients (YNPFIRE200 & LAGYNPFIRE200)	−0.21203 (s.e. 0.0488)	−0.21203 (s.e. 0.0388)
Visitation effets of fire		
Annual loss in visitation (annual)	(35 297)[A]	−4515
Percent non-resident visitation	92%	92%
Loss in non-resident visitation	−32 473	−4154
Expenditure effects of fire		
Average 17-county spending per non-resident visitor (US$)	187.85 (s.e. 19.76)	187.85 (s.e. 19.76)
Loss in visitor spending (US$)	−6 100 000.00	−780 335.06
Visitor WTP effects of fire		
Average visitor WTP per trip (US$)	136.00	136.00
Average annual net present value loss in visitor WTP due to fire (US$)	−7 932 000.00	−1 014 000.00
Marginal benefit per acre of fire avoidance		
Marginal visitor expenditure benefit (US$)	36.69 (s.e. 8.45)	
Marginal WTP benefit (US$)[B]	43.82 (s.e. 8.02)	

[A]Calculations are based on actual year-specific fire data, undiscounted for expenditures and compounded at 3% real for WTP, thus totals may vary from simple calculations from table entries.
[B]Standard error of marginal WTP benefit is based only on variability of YNPFIRE200 and LAGYNPFIRE200.

Based on an estimated average annual loss of US$6.1 million in direct expenditures due to fire activity in or near YNP, in an average fire year it is estimated that total output within the 17-county GYA is reduced by US$9.8 million when compared to a year with no fire activity. It should be noted that this estimate is conservative in that it is narrowly tailored to spending within YNP and surrounding contiguous counties. Table 8 also includes an estimate of total losses to YNP visitors in a benefit–cost accounting framework in terms of foregone benefits, or WTP, due to fire activity. Based on actual year-specific fire activity, an estimated WTP per YNP visit of US$136.00, and an assumed real discount rate of 3%, the estimated average annual loss in visitor WTP over the period due to fire is US$7.9 million, or a net present value of US$206 million over the 26-year period. Also shown in Table 8 are estimates for the median fire year acres burned. These estimated effects based on a median rather than mean fire year are ~13% of the estimated mean year effects. This again underscores the large variation in severity of fire years, and the fact that severe fire years have a disproportional effect on the average.

In terms of the marginal economic benefits of wildfire avoidance, for the current year, avoiding 1 acre (~4046.8 m^2) of wildfire within 100 miles (~160.9 km) of YNP is associated with US$36.69 (s.e. US$8.45) in direct visitor expenditure benefits, and US$43.82 (s.e. US$8.02) in visitor WTP.

Discussion

Marginal visitation effects

Our findings support our working hypothesis that proximate wildland fire has measurable and statistically significant concurrent effects on aggregate visitation at our study site, Yellowstone National Park. We found statistically significant effects of total cumulative acres burning in a given month at various levels of proximity including up to 50, 100 and 200 miles (~80.5, ~160.9 and ~321.9 km) distant for the period 1986–2011. We also found that, although consistent and relatively stable across increasing distance, these effects are also relatively small. For example (Table 8), for YNP, we estimate the loss in visitation for an average fire year for the period is 35 297 visitors or ~1.3% of the annual average Yellowstone visitation for the period. The effect for a median fire year is much less (reflecting the skew in acres (hectares) burned per year), at 4154 visitors or 0.2% of annual average visitation. The concurrent effect of wildland fire acres on park visitation is relatively stable across subsamples of the period (e.g. 1999–2009 period versus 1986–2011), time steps (monthly versus annual). The effect is also stable when the largest outlier year (1988) is excluded from the sample. For example, the elasticity of visitation with respect to acres burned across these disparate datasets and models is −0.0127 for the Yellowstone monthly model (combined concurrent and lagged effect acres burned within 200 miles (~321.9 km), and −0.0062 for the Yellowstone annual model (acres burned per year within the park).

We also found a statistically significant effect of wildland fire acres in the prior month; these lagged inter-temporal effects are generally twice the magnitude of the concurrent effects (Table 2). However, we found no statistically significant effect of acres burned in the previous year in the annual Yellowstone model for total visitation fitted to data for 1972–2009. We also reject this 1-year lagged effect for backcountry visitation, although this estimated parameter is of the expected sign and closer to being statistically significant. As one would expect given, greater physical proximity to the fire, backcountry visits are more responsive to acres burned (elasticity of visits with respect to acres burned per year within the park is −0.0162) compared to total visitation (elasticity of −0.0062). Taken together, these findings suggest that the lagged effects for proximate fires on visitation to these national parks are at the monthly level, but not over 1 year, let alone many years. This contrasts with the prior literature that focuses on post-fire at-the-site effects of a burned landscape, where effects on visitation have been estimated for up to 60 years (e.g. Loomis *et al.* 2001; Hesseln *et al.* 2003, 2004; Boxall and Englin 2008). However, the methods of the current paper differ in that they include off-site fires, are based on actual observed behaviour over time, and do not include stated preference data. This issue could be explored more fully (and made more comparable to previous research) by using time-series data on observed backcountry use and associated fire data disaggregated from the park level to sub-regions of a given park, or even to the level of individual trails or campsite. However, such disaggregated use data may not be readily available.

We also investigate cross-site effects and find that Yellowstone and Glacier (which are located 360 miles, or ~579.3 km, apart) appear to be complements (rather than substitutes) in that increased fire activity proximate to GNP on net reduces visitation at YNP.

WTP estimates

Our remaining hypothesis concerned response to the key explanatory variables suggested by economic theory, price and income. We found statistically significant effects of the theoretically consistent (price ÷ income) specification for both monthly and annual Yellowstone models. When the Yellowstone annual model is estimated on price and income separately, they are again statistically significant, of the expected signs, and the relative elasticities (−0.200 for price and +0.720 for income) are plausible. We use the annual Yellowstone travel cost model fitted to aggregate visitation and a travel cost parameter to estimate average visitor WTP at US$136.00. This is similar to our findings for the individual count data travel cost model fitted to 2005–2006 survey data at US$175.00 for WTP (Table 7). These values are also similar to WTP for outdoor recreation visits for multiday trips reported in the literature (Loomis 2005).

Challenges: marginal effects, WTP, budget constraints and benefit transfer

Combining our visitation effects parameter with our WTP estimates results in a marginal WTP benefit of US$43.82 (s.e. US$8.02) per acre (US$108.28 ha^{-1}) for the concurrent and lagged effect of wildland fires proximate to YNP (Table 8). Although the visitation effects are relatively small, they are for a nationally significant resource and average US$7.9 million or a present net worth in 2012 (at 3.0% real discount) of US$206 million over the 1986–2011 period. These results provide at least an example (and just for recreational use) of the feasibility of meeting the challenge posed by Venn and Calkin (2011) of estimating marginal effects and marginal benefits for nonmarket uses. We also demonstrate methods that meet the challenge of estimates that are consistent with economic theory and the consumer budget constraint; this follows from the fact that our estimates (unlike most of the prior literature) are entirely based on observed behaviour and revealed preference models and do not include stated preference approaches. Finally, we also demonstrate methods that are feasible using aggregate visitation data at the park-site level and do not rely on benefit transfer for estimates of WTP.

In addition to demonstrating methods for marginal effects of wildland fire on recreation within an applied welfare economics (benefit–cost) framework, we also demonstrate marginal effects in a regional economic accounting framework. For YNP, marginal visitor expenditures of US$36.69 per acre (US$90.66 ha^{-1}). Using a regional input-output model (IMPLAN) and a dataset for the 17-county GYA, we estimate direct effects of US$6.1 million of foregone non-resident spending per year for 1986–2011 and (including direct, indirect and induced effects) cumulative effects on gross product for this GYA economy of US$159 million. These estimates represent a very minor proportion of estimated YNP annual visitor direct recreational spending (Stynes *et al.* 2000).

Future research and wider applicability of the methods

We expect that our methods have wide applicability to many of the 396 other units in the US National Park System. All of these units have long-term visitation data and they include a wide variety of ecosystem types and geophysical settings. It would be of interest to examine other parks for differences in marginal wildland fire effects on visitation across ecosystem type, park type (national parks, national monuments, recreation areas, historical parks), region, and geo-physical and cultural setting. Future park applications would benefit from the high proportion of parks where prior visitor survey data, often from studies undertaken by the Visitor Survey Project at the University of Idaho[F], exists that could support WTP estimates (Heberling and Templeton 2009). The methods demonstrated here are in principle applicable not only to other parks, but to any recreation sites with long-term monthly or annual visitation data that are within the area of the USA covered by the National Fire and Aviation Management Web Application website. For example, the authors are aware of state park units throughout the western USA that charge entrance fees and report annual visitation statistics.

Of considerable interest would be estimating aggregate fire-visitation effects and travel cost models from long-term visitation data for the national forests. The USDA Forest Service did not begin its statistically valid visitor survey program, the National Visitor Use Monitoring (NVUM), until 2000 (Bowker *et al.* 2009). This program samples over 100 000 national forest visitors per year, rotating through 20% of the national forests each year. It may be possible that current or future data could support modelling of the type reported here, perhaps by using a combined cross-section and time series dataset. An attractive aspect of the NVUM is that it is designed to not only count visitors but also generate WTP estimates for 14 different types of recreation activity and for four macroregions. This continues a long history

[F]A listing of all reports and surveys by the NPS Visitor Services Project can be obtained from http://www.psu.uidaho.edu/vsp.reports.htm (accessed 15 March 2012).

in the US Forest Service (Duffield 1989) of estimating recreation use values, beginning with Sorg and Loomis (1984).

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