Assessing the Recreation Values at Risk from Wildfire: An Exploratory Analysis

Anish Neupane[1], Peter C. Boxall[1] and Rick Pelletier[2]

[1] Department of Rural Economy, University of Alberta, Edmonton AB, T6H 2H1

[2] Department of Renewable Resources, University of Alberta, Edmonton AB, T6H 2H1

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Introduction

The levels of participation in various types of outdoor recreation in forested areas are substantial. Williamson et al. (2002) have shown that over 18.5 million days, representing approximately 80% of recreation user days, were spent by Canadians in recreational activities in forested lands. Furthermore, recreation has significant social and economic value that should be reflected in management decisions if sustainable forest management is to be achieved. The importance of recreation in forests has resulted in the selection of measures of recreation participation as relevant indicators of sustainable forest management reporting in Canada (CCFM 2000). These facts, along with future projections of increasing recreational use of forests, suggest that recreation areas should be an important component of the values at risk of loss from wildfire.

The presence of recreationists, who are considered the highest values at risk, dispersed on fire prone landscapes present some issues for fire management agencies. These issues include the possibility of recreationists perishing in a wildfire and/or the possibility of fire ignition as a result of recreation activities. For fire management agencies that strive to suppress all wildfires, the latter issue is particularly challenging when faced with fire suppression resource constraints. Thus, a move away from suppression of all wildfires to suppression based on protecting highest values at risk is needed. An explicit incorporation of recreation values is advantageous in that these values are closely linked to the presence of recreationists and recreation infrastructure. However, infrastructure may not necessarily reflect high recreation value. Therefore, during fire events, directing resources to high value recreation areas fulfill a fire management goal of protecting highest values at risk, as well as identifying areas of the landscape where the suppression efforts are to be directed.

This paper reports on research which focuses on developing spatially explicit indicators of forest recreation to be incorporated into a fire management zoning scheme or values at risk map (VARM) for the province of Alberta, Canada. Rather than assume that the presence of infrastructure reflects value, this research models recreation demand using infrastructure and other site-specific attributes of the landscape. In this study, the spatial nature of recreation data is explicitly incorporated by modeling visits to area as a function of the biophysical attributes of the site and of the surrounding sites. Given the underlying data structure, we employed econometric procedures to estimate the levels of recreation use in a spatial manner across the province.

The Study Area

The area of study is the province of Alberta, Canada (Figure 1). The boreal forests cover approximately 60% of Alberta's northern landmass. Mountain and foothill ecosystems also support forests which are highly sought for recreational purposes. The majority of these forests are located on public lands (SRD 2003). In addition to supporting human activities, such as resource extraction, the forests also provide numerous opportunities for outdoor recreation. These opportunities are exhibited in Figure 1a. Given that fire occurrences are frequent in most of the forest ecosystems in the province, many of those activities and infrastructure are at risk of loss from wildfires. In response to this fire risk, the province, through its Forest Protection Program, carries out fire management activities to minimize the impacts of wildland fires.

Forest Fire Management in Alberta

Fire management in Alberta has been driven by the broadly stated goals of reducing the impact of fire on people, property and resources (Alberta Fire Review 1999; Chisholm Fire Review Committee 2001). Specifically, firefighting resource allocation priorities, in decreasing order of importance, are: protection of human life, communities, sensitive watershed and soils, natural resources and infrastructure (SRD 2003). These priorities are collectively termed "values at risk". Recreation values at present are not specifically included. However, these values are currently assumed to be reflected through the presence of publicly provided recreation infrastructure at a site. The implicit assumption is that the costs of replacing lost infrastructure due to fires at the sites determine the economic values of recreation. A map of this infrastructure is presented as 100 km^2 grid cells is shown in Figure 1. This infrastructure includes campgrounds located in provincial parks and recreation areas as well as wildland areas. The borders of four of the large national parks (Wood Buffalo, Jasper, Banff and Waterton) are also shown on this map, and a number of areas in these parks also contains infrastructure.

Recreation values, however, should include the value associated with participating in the activity, and this may be or may not be associated with provincially funded infrastructure. Thus, explicit consideration of recreation values in allocating resources would be advantageous in that these values are closely linked to the presence of recreationists and not necessarily infrastructure. Therefore, during fire events, directing resources to high value recreation areas fulfill a fire management goal of protecting highest values at risk, as well as identifying areas of the landscape where the suppression efforts are to be directed.

Methods

Examining recreation participation in the province in a spatial economic manner is a challenging task. Many recreation trips take place on lands that are not subject to spatially referenced permits or registrations as would be found at campgrounds or parks. These types of trips are called random camping by many practitioners. Furthermore, databases of registrations and permits that arise from government or private camping operations are not constructed in a consistent manner which prevents their use in a project of this nature. The only spatially referenced recreation data we found available was obtained from the 1996 National Survey on the Importance of Nature to Canadians (NSINC).[1]

The NSINC survey was conducted by Statistics Canada in 1997 and included a provincial sample of 2,353 individuals drawn at random from the provincial population. These individuals took 22,204 trips to areas throughout the province in that year. The survey incorporated statistical procedures to allow analysts to develop estimates of total recreation use by the provincial population at sub-provincial levels. Respondents to this survey provided a variety of information, including, their levels of participation, for the following categories of activities: general outdoor recreation (camping, picnicking, off-road vehicle use etc), wildlife study (bird watching etc), fishing and hunting. Respondents also provided information on the locations to the nearest human settlement of the most frequently visited sites for trips within each of the four categories. These trips were mapped (see Figure 1b) using a geographical information system (GIS) to provide the most recent the spatial distribution of levels of recreation participation. It is apparent that the distribution of activity does not reflect the distribution of the government provided infrastructure shown in Fig. 1a.

[1] Defined as Alberta residents who went to Alberta destinations.

Note that the location of recreation trips was specified according to proximity to human settlements. This geo-reference likely contains error in location. This, and the fact that spatial information about the recreation locales was required to determine what influenced the level of activity and to predict future recreation use, resulted in the development of spatial units. The choice of the spatial unit rather than using the specific "point" location allowed some consideration of the error in location as well as the development of indicators of relative attractiveness of the units for recreation.

The spatial unit can be specified using a variety of methods including, among others, buffering (Hunt et. al. 2004), using administrative areas (Monchuk and Miranowski 2003) or constructing geometric areas (Bateman et al. 1999; Bateman and Lovett 2000). This typically involves hexagon tessellation. A review of literature, however, found that recreation studies (Bateman and Lovett 2000; Bateman et. al 1999) have used grid tessellation. Further impetus for selecting the grids tessellation came from research partners as well. Thus, we chose to define our spatial unit of analysis in equal area grids.

The selection of grid size was motivated by several factors. A review of literature provided no definitive guidance on the issue other than to caution researchers to use a grid size appropriate to the specific research (Kuo et al. 1999; Harrison and Dunn 1993). Previous recreation demand studies experimented with varying grid sizes such as 0.25 km^2 (Brainard et al. 1999), 1 km^2 (Bateman et al. 1996) and 25 km^2 (Bateman and Lovett 2000). Harrison and Dunn (1993) show that there are substantial gains to be had, in terms of consistency of the results, in moving to a smaller unit of analysis. However, this must be balanced with the fact that smaller units of analysis have significant computational requirements. Bateman et al. (1999) investigate this issue further and find that additional detail afforded by using finer grid sizes must be balanced with the large increase in computing time. These findings suggest that grid size choice is a function of the research being conducted.

Two grid sizes were examined in preliminary experimentation, a 25 km^2 grid cell size which resulted in 26,516 grid in the province, and a 100 km^2 grid which yielded 6,618 grids in the province. Query analysis in ArcView showed that the 25 km^2 grid had 361 grids that contained at least one trip location, while the 100 km^2 configuration had 341 grids that contained at least one data point. However, the more even distribution of the data in the 25 km^2 configuration must be balanced with the significantly less computational time requirement for the 100 km^2 grid size. Furthermore, the first grid offers better distribution than the second grid by less than a third of a percent (21/6618). Given the hypothesis, an additional factor in that decision was distance consideration. The greatest Euclidean distance is 42 km (between the farthest corners of the farthest neighbours). Since a majority of the recreationists are assumed to use motorized vehicles to access areas, it is reasonable to assume that this distance can be considered within a recreationists' choice of site. Thus, 100 km^2 grid was chosen.

<u>Landscape attributes</u>

Alberta Sustainable Resource Development (SRD) provided landscape attribute data for the province in a GIS format. This data contained landscape features such as road networks, hydrological features, human settlements, forest cover and fire history. Some of the hydrological features exhibited a significant degree of collinearity and were dropped from the analysis. The remaining water features were aggregated and their areas converted to shoreline lengths. We felt that this provided a better measure of recreational access to water bodies. Human settlement consisted of large cities to small villages. In preliminary estimations, the low level of statistical significance for fire history led this variable being dropped from the final regression models discussed below.[2]

Information from the 1996 census was used to determine if population in proximity to cells had an influence on their levels of recreation. The NSINC data contained information on the distances travelled, and the median, 25 and 75 quartiles from this distance information was calculated. The population levels within these distances for each cell were estimated and used as independent variables. Based on preliminary model estimations, the median one-way distance travelled (120 km) from the survey was used. Note however, that population levels from neighbouring provinces next to Alberta's boundaries were excluded from this variable.

Table 1 provides a description of the final set of independent variables used in the regression analysis and their associated descriptive statistics.

Econometric Modelling

Spatial econometrics deals with the estimation and specification of problems that arise from spatial autocorrelation in cross-sectional data (Anselin and Bera 1998). Those problems can be attributed to either structural relationships among the observations (lagged dependency) or the spatial dependency among the error terms as a result of the omission of correlated explanatory variables (Hunt et al. 2004). Researchers have shown the importance of accounting for spatial relationships in fields such as hedonic applications (Can 1990; Pace and LeSage 2002) and technological adoption (Case 1992, Dubin 1995). This interest in spatial econometrics can be attributed to two additional factors (Anselin 1999). First, the theoretical economic models have begun to move a way from an individual decision maker acting in isolation to an explicit

[2] This may stem from poor available data. We only had access to data for E-class fires; these fires are those that reach over 200 hectares in size.

accounting of that individual's interaction with other factors in the environment. For example, Brainard et. al (2001) find that recreation site choice is influenced by biophysical attributes of the surrounding landscape. Furthermore, advances in techniques such as GIS, can deal with spatial data from a practical, applied perspective and this has provided added impetus for growing interest in spatial econometrics.

Anselin (1988) suggests the following equation that captures both possible spatial dependencies.

$$Y = a + r W_1 y + b X + e$$

where $e = l W_2 + m$, with $m \sim N(0,W)$. The model includes, W_1, the spatial weights matrix, a coefficient for the spatially lagged variable (r), a possibly different spatial weights matrix (W_2), and a coefficient (l) for the spatial autoregressive structure for the disturbance (e). Additionally, a and b (a vector) are parameters to be estimated and X is a matrix of independent variables. A non-zero l represents spatial error which leads to unbiased yet inefficient statistical inferences if estimated using ordinary least squares (OLS) (Anselin 1988). A non-zero r value represents a spatial lag which leads to biased and inconsistent statistical inferences if estimated using OLS (Anselin 1992b).

A challenge using these techniques is the specification of the spatial relationship among n observations which is captured by the weight matrix, W, with n x n dimensions. This matrix is characterized by zeros along the main diagonal and has off diagonal elements representing neighbours. These neighbours can be specified using a variety of methods including distance based criteria (Anselin 1988; Acs et al. 2002) and contiguity measures (Anselin 1988; Pace and Lesage 2003). For this study we employed a first order contiguity (queen configuration) weights matrix with a value of 1.0 for neighbours. This spatial configuration essentially involves the eight neighbours that are connected to each grid cell which has at least one observed trip from the NSINC data. This choice of a weights matrix resulted in the sample size of 3872 grid cells.

Testing for spatial dependencies

A method to estimate jointly the spatial lag and the spatial error is currently unavailable (Hunt et. al. 2004). As such, a researcher must select a spatial autoregressive model by testing for r or l through several tests based from the unrestricted, OLS, model ($r = 0$, $l = 0$). These tests could suggest that both spatial lag and error model are appropriate (ibid). However, if using Lagrange Multiplier (LM) tests, the preferred model will have the higher χ^2 (Anselin and Rey 1991). These models are typically estimated using maximum likelihood procedures, but other approaches are possible. Despite the wide array of estimation methods available, research suggests that parameter estimates are likely to be impacted more by the choice of a spatial weights matrix than by the chosen estimation technique (Bell and Bockstael 2000).

These procedures are applied to the grid cell map of the province in order to understand the influences of grid cell characteristics and cell neighbours on recreation trips. In addition to the standard diagnostic tests the prediction performance of each model was examined by generating a hold-out sample of grid cells. This sample involved a random selection of about 10% of the cells (N=386) which were left out of the estimations. The ability of the models to predict the trips in this hold-out sample provided a further indicator of performance.

Results

Table 2 provides the parameter estimates of the OLS and other models and the diagnostics for the two sources of spatial dependencies. These diagnostics are computed based on LM tests and are shown to be robust (Anselin et. al 1996). These tests led to rejection of the hypothesis of no spatial dependence. As suggested by Anselin and Rey (1991), a mixed regressive-spatial autoregressive model[3] was chosen since the LM test value was higher for the spatial lag than the spatial error. The parameter estimate for the lag coefficient r is -0.1104 suggesting that there is a negative spatial correlation between trips at a grid and its neighbours.

The inclusion of spatial lag in the model did not change appreciably change the OLS parameters which is not surprising given the relatively small lag coefficient. Using the spatial lag term, the dependent variable of the original OLS model was "filtered" using the equation below.

$$(Y - pWY) = a + bX + e$$

The standard errors of the parameters resulting from an OLS model estimated on this filtered data were then corrected using White's hetereoscedasticity correction. This resulted in few adjustments to the significance levels of the parameters.

The signs on the parameters were not all as expected. The inclusion of campgrounds, the presence of human settlements in particular regions of the province and the population variables were all positively related with trips to a cell. The campground variable (CMPG) was positive and significant, reflecting the fact that recreationists are drawn to areas with campgrounds for recreation. The dummy variables, SETNORTH and SETMTN were both positive and significant. This suggests that the presence of human settlement in these two regions was an important determinant of recreation site choice. The population variable, while positive was found to be

[3] where $\rho \neq 0$ and $\lambda = 0$

not statistically significant. This is rather surprising given that previous recreation demand studies (Brainard et. al 1997; Bateman et. al 1996) have found the population sizes in proximity to recreation areas to be significant determinants of recreation demand.[4]

The linear parameter on the amount of water area had a significant positive effect on the numbers of trips. However, the significant negative parameter for the quadratic of that variable suggests that increasing amounts of water area are initially positive, but this effect declines at an increasing rate, eventually having a negative impact on the trip level in a cell. This non-linear effect confirms to prior expectations.

The parameter estimates on the linear and quadratic parameters for the road access variable suggest a convex relationship with trip levels. While the number of trips initially declines as road access increases, trip levels eventually become positively associated with roads. This relationship can be explained by the fact that while higher density of roads offers access, it restricts the amount of recreation opportunities that is available. This may be particularly true near population centres where road types are not conducive to recreational activities such as wildlife viewing, dirt biking and off road vehicle use. In contrast, the road networks away from the population centres are more suitable to such activities and would be expected to provide better recreational opportunities.[5] While we did not test this hypothesis, anecdotal evidence suggests this likely occurs.

The parameter on the forest variable was negative and was contrary to prior expectation as previous recreation studies (Brainard et. al 2001; Bateman and Lovett 2000) found forest cover to be positively related to recreation levels. Our result may be related to the fact that considerable recreation trips occur in non-forested areas in the province. This can be seen in Fig

[4] The population variable could be correlated with the road variable given that road networks often exist around human settlements. However, preliminary data analysis suggested such correlation to be relatively low at -0.19.
[5] These recreational opportunities exist largely because of the network of logging roads (McLevin pers. comm.)

1b which shows the distribution of trips throughout the province from the NSINC data. The results we derived could stem from our use of crude forest data, although we do did not test this since better quality data was not readily available.

While the spatial econometric model did not seem to offer any significant advantages over the linear OLS model, we considered the censored nature[6] of the trip data in the cells subjected to analysis. Essentially about 90% of the cells exhibited a trip level of zero. Given this underlying data structure, we also estimated a Tobit model on these data. The last column of Table 2 provides parameter estimates for this Tobit model.[7] The signs of the parameters were similar to the OLS specifications and there are no serious differences in the significance levels.

The regression models presented in Table 2 were used to predict the number of trips in the hold-out sample. The results for both out of sample and within sample prediction are shown in Table 3. These results suggest that the OLS model performed the best at predicting the total number of trips in the hold out sample. We are still conducting tests of the prediction performance of these (and other) models, so the results reported below are preliminary.

We used the OLS, OLS-lag and Tobit regression models to predict the distribution of trips across the province. The predictions were placed into categories and are displayed in maps in Figure 2. Blank spots in the maps show areas where the models predict 0 trips. Note that these maps involve the spatial pattern of trip categories, not actual trips. This results in the TOBIT and OLS map looking similar when in fact they are not.

All three models predict significant levels of activity near the major population centres of Edmonton, Calgary, and Lethbridge. The OLS and TOBIT models also predict high trip levels to cells near the smaller population centres such as Peace River in the north and Red Deer in the

[6] Censored data refers to cases where observations are recorded only as above or below some threshold
[7] Note that this model is not a spatial tobit model – we are currently exploring the use of this model.

central part of the province. The OLS lag model appears to predict significant recreation activity in the northern parts of the province. There are few people living there, and few people from other parts of the province visit this region. The OLS and TOBIT models however, suggest a different pattern of trips, with few areas of the north providing destinations for recreation trips. The OLS lag model on the other hand, suggests that few trips were taken to the southeastern region which may be a better representation of reality. Based on these a priori expectations and cursory examination, it appears that the OLS lag does a more realistic job of predicting the spatial pattern of recreation in the western mountain region and the southern portion of the province, while the OLS and TOBIT models appear to be better at doing this in the north.

Discussion and Conclusions

These findings suggest that the infrastructure map does not provide an accurate spatial depiction of recreation values. There are significant recreation areas in proximity to population centres in the province that do not depend on infrastructure. While this seems an obvious conclusion, the fire management agency was interested in knowing more about recreation values in forests in or near urban areas. These forests were not specifically identified in the model as they are not part of the traditional forest inventory. The models examined in this study seem to identify this and suggest that in terms of "value" these areas maybe more significant than those in the traditional sphere of the fire management staff which largely involves industrial managed forests under tenure to the forest industry.

In terms of value, the NSINC data when inflated to the provincial level, suggest that Albertans took about 12 million trips to natural areas and a further 10.5 million trips to view or hunt wildlife and /or fish and these trips consumed about 33.5 million days. (DuWors et al.

1999). The survey also collected estimates of consumer surplus associated with these activities (FPT Task Force 2000) and ranged from about $6.00 to $15.00 per day depending on the activity. Assuming the trip activities examined in this study include wildlife viewing, hunting and outdoor activities in natural areas, a weighting average of the consumer surplus per trip was calculated to be about $13.00/trip in 1996. The next step in the development of a values at risk map would be to convert the predicted trips to estimated economic values using this surplus measure and the provincial level of the number of trips. The development of this map is currently underway.

It is unfortunate that the most comprehensive data available to conduct analyses such as this are rudimentary in nature and out-dated. The NSINC information is the only available data on recreation trips throughout the province that could be found to conduct this analysis. Furthermore, the inaccuracies involved in the spatial referencing of this information will require a more thorough analysis of spatial econometric concerns than we report here. We are presently examining other approaches.

In addition, the notions of recreation economic value developed here are static and rudimentary. The "true" economic values of trips to locations in these cells are likely not to be the same across the province. Despite this, however, this study suggests that the spatial pattern and replacement costs of infrastructure would mis-represent the value of recreation in a values at risk framework. A study such as this represents a first step in developing more comprehensive approach to including recreation concerns in a wildfire management framework. It also illustrates the type of information required to conduct this analysis in future studies.

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Table 1. Variable definitions and mean values (standard deviations, where appropriate, in parenthesis) for the sample of trips (N=3872)

Label	Definition	Mean Value
Y	Number of trips that occurred in a cell from NSINC Min = 0, max = 2084	5.73 (57.318)
HPL	Shoreline of water body (km)	39.544 (66.56)
RD	Length of road (km)	63.398 (47.435)
FORST	Area of forest (km^2)	41.847 (47.934)
CMPG	Number of campgrounds	0.22 (1.00)
P120KT	Population within 120km radius (in thousands)	303.31 (422.77)
SETNORTH	Settlement that is north of Cold Lake (1 = northern community, 0 = southern community)	0.113
SETMTN	Settlement that is in close proximity to the mountains (1 = close to mountain, 0 = not close)	0.217

Table 2. Parameter estimates (standard errors) for four models explaining recreation trips to 100 km^2 grid cells in Alberta.

Variables	OLS	OLS lag	OLS lag (Hetero corrected)	Tobit (normalized coefficient)
Constant	3.0909 (2.9442)	4.5461 (2.9376)	4.5460 (4.5271)	-2.6916 ** (0.1402)
HPL	0.0960 ** (0.0302)	0.0973 ** (0.0301)	0.0973 ** (0.0374)	0.0040 ** (0.0013)
HPL2	-0.0002 ** (0.0001)	-0.0002 ** (0.0001)	-0.00023** (0.0001)	-0.0000 * (0.0000)
RD	-0.2083 ** (0.0532)	-0.2333 ** (0.0530)	-0.2333 * (0.1366)	0.0129 ** (0.0021)
RD2	0.0021 ** (0.0003)	0.0022 ** (0.0003)	0.0022 ** (0.0009)	-0.0000 (0.0000)
FOREST	-0.0626 ** (0.0239)	-0.0711 ** (0.0238)	-0.0711 * (0.0368)	-0.0037 ** (0.0011)
CMPG	3.3319 ** (0.9137)	3.4281 ** (0.9107)	3.4281 (3.5380)	0.0949 ** (0.0245)
P120kt	0.0005 (0.0025)	0.0012 (0.0025)	0.0012 (0.0038)	0.0002 ** (0.0001)
SETNORTH	3.7093 (2.9629)	3.8654 (2.9507)	3.8654 ** (1.5440)	0.5922 ** (0.1552)
SETMTN	77.4628 ** (6.2262)	80.1591** (6.2522)	80.1590** (32.2593)	1.4556 ** (0.1552)
s				211.0460
?		-0.1104		
LLF	-21013.9	-21006.2	-21002.83	-2802.1780
R^2	0.077	0.0840	0.0840	
LM lag	5.51**		0.006	
LM error	1.71			
LR test ($?^2$)		15.53		

* Significant at the 10% level
** Significant at the 5% level or better

Table 3. Measures of the prediction performance of the four regression models using a holdout sample of cells.

Prediction performance measures	OLS	OLS lag	TOBIT
MAE (mean $\|Y_{actual}-Y_{predicted}\|$)	10.63		11.90
% actual cells with 0 trips	45		23
No. of predicted trips (actual=2178)	2824		3869

Figure 1. a) Maps of the recreation infrastructure and National Park boundaries for the province of Alberta; b) A map of the spatial distribution of recreation trips taken by Albertans in 1996 for wildlife viewing, hunting, fishing and general outdoor activity in natural areas.

Figure 2. Maps of the predicted distribution of NSINCS trips using various regression models. a) linear OLS results; b) OLS spatial lag results; and c) TOBIT model results.

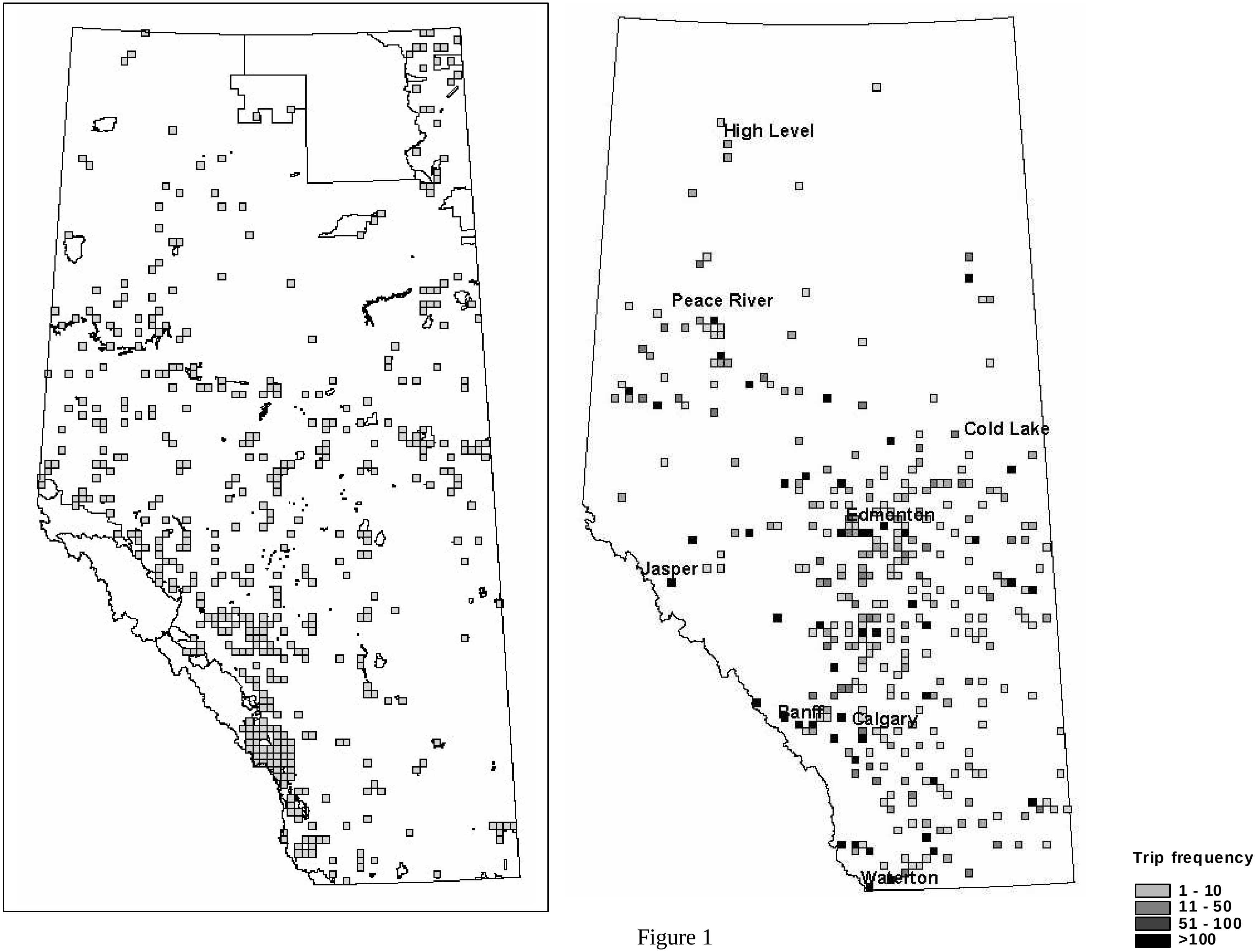
High Level
Peace River
Cold Lake
Edmonton
Jasper
Banff
Calgary
Waterton
Trip frequency
1 - 10
11 - 50
51 - 100
>100

Figure 1

OLS | OLS-lag | TOBIT

Figure 2

Trip frequency

- 1 - 10
- 11 - 50
- 51 - 100
- >100