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Abstract: Recent years have witnessed growing interest in the critical role of local/regional governance structures in shaping physical land development and associated natural resource management processes. This article investigates how political fragmentation in local governance can affect land use patterns through a watershed-level analysis of population and employment density changes in the Interior Plains, the largest physiographic division of the U.S. Population density change rates are found to be negatively associated with a higher degree of political fragmentation, while employment density does not show such a clear relationship with political fragmentation. This finding shows that political fragmentation may present significant challenges to land and water resource management, a result consistent with previous empirical research.

Key Words: Land Use; Resource Management; Local Governance; Political Fragmentation; Development Density

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Political Fragmentation and Land Use Changes in the Interior Plains

1. Introduction

In both developed and developing countries, there has been growing concern about the sustainability of our natural resource management, as the resources that are essential for the viability of basic human life have increasingly deteriorated or been depleted (see e.g., Acheson, 2006; Knight and Rosa 2012; Sherval and Askew 2012). Although unsuccessful resource management outcomes could be attributed to myriad causes, one of the most important factors determining the success/failure of resource management is the quality of institutional arrangements that fundamentally shape how we utilize resources and how we respond to emerging environmental issues (Stroup 1991). In other words, "getting institutions right" (Rodrik 2004) is crucial in environmental planning and effective management of our resources as well as other policy making domains.

Admittedly, the importance of human institutions in resource management has long been recognized. Hardin's (1968) 'tragedy of the commons' and the well-known work of Elinor Ostrom (1990, 1999, and 2000) highlighted the importance of institutional structures in the arena, although their conclusions differ. Yaffee (1997) also underscored problematic consequences of fragmented institutional structures (i.e., scattered responsibilities in resource management or other relevant tasks) as a major cause of recurrent failure in natural resource management. Multiple players with fragmented authority, according to the argument, are likely to generate inconclusive decision-making and piecemeal solutions that cannot guarantee successful management outcomes for a society. More recently, Kunce and Shogren (2005) suggested that decentralized governance systems combined with fiscal constraints can be harmful as they tend to invigorate environmentally destructive competition, even though there could be substantial comparative advantages of local decision-making over top-down approaches. According to Kunce and Shogren (2005), when local governments have gains from lax environmental standards (or the gains exceed the amount of pollution losses), "the jurisdiction possesses strong incentives to reduce environmental quality standards in order to attract the much needed capital tax base" (p. 222), suggesting that resource management outcomes can be significantly affected by the way our institutions, particularly governance structures, are organized.

This study empirically investigates critical implications of the institutional arrangement for resource management, specifically small watershed-level land use changes. More directly, it analyzes how political fragmentation in local governance – a critical element of the institutional environment associated with resource management practice – affected land use pattern changes between 1992 and 2001 in individual watersheds. The area of concern here is the Interior Plains, the largest physiographic division of the U.S., where a large degree of heterogeneity exists in terms of local governance structures ranging from highly fragmented situations to more consolidated settings.

The following sections first provide a brief discussion as to why and how political fragmentation can shape land use patterns by reviewing a group of relevant studies. The remainder of this article then explains the present study's methodology along with a description of variables (including the metrics of political fragmentation) and the data employed (section 3). Empirical analysis results are presented in section 4, followed by a concluding section in which the entire research is summarized and discussed. Overall, this study attempts to unveil the implications of political fragmentation for land and water resources which are essential for the public health, welfare, and prosperity.

2. Political Fragmentation in Local Governance and Land Use Patterns

Although the exact distribution of authorities varies from country to country, local government units play an influential role in resource management for their residents and businesses. In the U.S. and many other countries, local governments are the entities, among various institutions, formulating community goals and policy actions that can directly or indirectly guide the management of their resources (Brody 2003; Kauneckis and Andersson 2009). Furthermore, local governance structures largely shape the ground rules which determine the behavioral patterns of various actors in both public and private sectors, and thus can influence almost every element of our society including land use processes and outcomes (Kim and Jurey 2013).

A great deal of scholarly attention has been paid to how governance structures can influence local policy-making and outcomes and what would constitute a desirable form of governance, given rapidly changing demographics in the U.S. Tiebout (1956), Brennan and Buchanan (1980), and other public choice theorists suggest that a disaggregated (or non-monopolistic) structure can satisfy diverse residents' preferences and lead to a more efficient state. In their view, public welfare can be promoted when a wide range of tax and public service packages are provided by a number of localities which are competing with others, as consumers can be benefitted by additional producers in a market system. Moreover, it is also claimed that government agencies at multiple tiers are sometimes needed to meet a variety of public interests in an increasingly diversified society and cope with multi-dimensional social problems more effectively (Nagendra and Ostrom, 2012; Ostrom et al., 1999; Neef, 2009).

In contrast, other groups of scholars advocate a more consolidated structure of governance. They contend that a large number of small governments are likely to present significant disadvantages in public service delivery due to difficulties in achieving economies of scale, avoiding unnecessary service duplication, or ensuring consistency in policy making or implementation (see e.g., Forbes and Zampelli, 1989; Deller and Rudnicki, 1992; Hendrick et al., 2011). A fragmented structure of governance has also been criticized as being unlikely to promote social equity or integration among various groups of population (see e.g., Weiher 1991; Dreier, Mollenkopf, and Swanstrom, 2001). According to Morgan and Mareschal (1999), racial segregation tends to be more serious in a region with a higher degree of political fragmentation. Recently, Hutson et al. (2012) reported a significant association between metropolitan governance fragmentation and racial disparities in mortality through their analysis of the data for 171 large U.S. metropolitan areas, although "[their] findings do not constitute proof of a causal association between [the two variables]" (p.201).

While numerous studies have investigated the important roles of local or regional governance, the literature examining how resource management can be influenced by governance structures is quite limited. Particularly, in the field of environmental studies, existing literature tends to explore the issue through individual case studies rather than assessing it through statistical, cross-sectional examination. In land use literature, "the influences of institutional conditions [including local governance settings] are often neglected, while attention has been paid to externalities [i.e., spillover effects], scale effects, and many other factors of [land] development" (Kim and Hewings 2013, p.197).

Recent studies in related branches of social sciences, however, have investigated the implications of local governance structures, particularly political fragmentation, in relation to land use and physical development processes. Lewis (1996) provided one of the early studies shedding light on this issue, particularly whether or not "local and regional political institutions have any systematic role in shaping urban form and the built landscape" (p.1) and how the governance settings can affect land development patterns. He paid explicit attention to the critical role of urban politics that underlay land use policy decision-making and development dynamics in urban areas. More specifically, a highly fragmented metropolis is more likely to be equipped with a political organization that resists a fundamental shift (e.g., transition from physical expansion based on low-density fringe development to reorientation of the growth momentum to the central areas) and thus shows continued suburban or exurban sprawl due to institutional inertia and/or local political coalition. According to Lewis (1996), the city of Denver and surrounding suburban municipalities showed this problem (i.e., massive development of the periphery), while the Portland metropolitan region, with a more consolidated structure of governance and land use planning, provided a counter-example in terms of physical development patterns.

Additional researchers have posited that political fragmentation can induce a more sprawling pattern of land development. Byun and Esparza (2005) traced the linkage between political fragmentation and sprawl using a four-stage framework in which emphasis was placed on the implementation/diffusion of local growth controls in a fragmented setting and the resultant spillover effects. In a fragmented setting, individual local governments may tend to focus on their own interests and local economic benefits rather than take a holistic view and/or collaborate with each other to set and achieve common goals.[1] Such parochial mentality often results in density restrictions or minimum lot-size zoning ordinances that prevent higher-density development, particularly in suburban communities. This, in turn, can force households to seek housing options in remote locations or other regions, as demonstrated in Shen (1996), Pendall (1999), and Kim and Hewings (2012), and thus aggravate the problem of sprawl that makes resource management more challenging as well as generates significant socio-demographic implications. Ulfarsson and Carruthers (2006) also provided a similar explanation of the linkage between political fragmentation and sprawl based on the well-known bid-rent model and Tiebout's (1956) theory, in which mobile households who can "vote with their feet" (i.e., choose their location of residence) are benefited by a greater number of municipalities providing a broad range of public service baskets and associated tax rates. According to the authors, "differences in taste or, more specifically, in the ability to pay for public services, account for the widespread municipal fragmentation … [leading] to greater homogeneity by way of division along socioeconomic, racial, and/or ethnic lines" (p.769-770). Further, this created a 'cycle of fragmentation and sprawl' – i.e., political fragmentation can cause sprawl and vice versa – given

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[1] Peterson (1981) examined why cities under competition with other municipalities tend to show a certain attitude by focusing on local politics and the benefits median taxpayers can get from additional development projects, as opposed to redistributive policies. A group of subsequent studies have also attempted to understand the nature of localities' behaviors in various settings. For instance, through a logistic regression analysis of the data for more than two hundred cities in the U.S., Basolo (2000) found that local governments tended to spend more on economic development than affordable housing projects when exposed to a high degree of interjurisdictional competition.

the environment (with respect to property tax, public service delivery, and municipal incorporation) prevalent in the U.S. that favored low-density residential development and tended to push metropolitan growth outward.

More recently, a few studies have attempted to empirically test whether a fragmented structure of local governance really induces a more sprawling pattern.[2] Razin and Rosentraub (2000) investigated the linkage between fragmentation and sprawl through a cross-sectional examination using the data for 98 Canadian and U.S. metropolitan regions. Although a positive correlation was found between political fragmentation metrics and sprawl indicators, the authors' ordinary least squares regression did not show "any significant impact on the composite measure of residential sprawl … or on any specific measure of sprawl" (p.834). In contrast, Carruthers and Ulfarsson (2002) showed empirical evidence for the connection between fragmentation and sprawl by conducting a county-level analysis based on a pooled data set covering 283 counties in fourteen selected states and three time points: years 1982, 1987, and 1992 for which the US Department of Agriculture's (USDA) National Resources Inventory information was available. Their analysis suggested that a more fragmented structure, indicated by a greater number of per capita municipal government units or per capita special districts, tended to show a lower urban density. A similar finding was reported by two subsequent studies performed by the same

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[2] It needs to be noted that Pendall (1999) provided an early empirical investigation of the effects of political fragmentation on sprawl. Although the influence of political fragmentation was not the main focus of the study, he tested the effects using two political fragmentation variables in his county-level analysis and detected a statistically significant coefficient for one of the fragmentation metrics suggesting that a more sprawling pattern was likely to be realized in a more fragmented context.

authors (Carruthers 2003; Ulfarsson and Carruthers 2006) in which a larger geographic scope was analyzed with the use of improved methods. Kim and Hewings (2013) took a slightly different approach. While the above studies investigated the association between political fragmentation and urban development outcomes by conducting regional or county-level analyses, Kim and Hewings (2013) concentrated on the micro-level land use change dynamics. More specifically, they tested if land use conversion rates at a micro scale (i.e., at the 1 mile × 1 mile section level) were affected by political fragmentation and resultant interjurisdictional competition. From analysis of over 100,000 sections in 82 Midwest metropolitan areas using a quasi-likelihood estimation method, they came up with a result suggesting that a fragmented setting can induce a more rapid land-use conversion for urban purposes (either residential or commercial-industrial) in the fringe areas.

In sum, it has been contended that political fragmentation can cause a more sprawling pattern of development that is often presumed to aggravate the plethora of problems related to resource management and planning: habitat fragmentation, loss of environmentally sensitive areas and biodiversity, water quality degradation, to name a few. Recently, multiple studies have considered the empirical validity of this claim (i.e., political fragmentation can lead to a sprawling patterns of land use) and have provided analysis outcomes that enhance our understanding of the nexus between local governance structures and land use patterns.

However, these studies often focused on a simple indictor of urban density levels, as opposed to net density changes or other metrics that can better represent the dynamics of the land use changes under the influence of governance structures. Razin and Rosentraub (2000) acknowledged this point by stating that "an analysis of measures of change could have been viewed as more appropriate for the study—for example, studying the relationship between fragmentation levels at the beginning of each decade with the change in population densities in the same decade (influenced by population growth and expansion of the urbanized area)" (p.825). Furthermore, the majority of previous empirical research has been conducted based on a political or administrative boundary (e.g., county) through analysis of aggregated data that would have limited usefulness in drawing salient lessons for resource management. Consequently, little is known about how local governance structures shape detailed land use patterns at a geographical scale that is relevant to land and water resource management. An empirical investigation that builds upon prior research but is conducted at a more appropriate scale can help fill research gaps and eventually provide meaningful insights into the critical linkages between governance structure and resource management.

3. Methodology and Data

3.1. Study Area

In this study, attention is paid to 31,485 small watersheds (i.e., 12-digit-level, which average about 40 square miles in area) falling in the Interior Plains and that account for more than 30% of the entire watershed areas in the contiguous U.S. The Interior Plains, which is the largest physiographic division in the U.S. delimited by US Geological Survey (USGS), stretches over 23 states including most of the Midwest states and contains various types of human settlements ranging from large cities to suburban and rural landscapes (figure 1).

<< Insert figure 1 about here >>

Figure 1. Study Area: The Interior Plains

Furthermore, the Interior Plains contain a broad range of heterogeneity in terms of local governance structures. For instance, Grand Forks, ND, Fargo-Moorhead, ND-MN, and some other metropolitan statistical areas (MSA) had more than one government units per 1,000 residents, while there are less than 0.1 (general- and special-purpose) governments for the same number of population in Odessa-Midland, TX and Clarksville-Hopkinsville, TN-KY MSA in year 1992. In addition, substantial variation exists in institutional arrangement at a small watershed scale. There are more than a thousand 12-digit-level watersheds which cross state boundaries, and approximately 15,000 watersheds are intersected by multiple counties. Moreover, a considerable number of watersheds are shared by multiple incorporated areas, whereas many other watersheds are managed by a single jurisdiction or located outside of any cities. An extreme case is found around Louisville, KY where a watershed was shared by more than 40 incorporated cities or towns (figure 2). Later, the city of Louisville was merged with Jefferson County, KY (see e.g., Savitch and Vogel (2004) for more detailed information about the city-county consolidation).

<< Insert figures 2 and 3 about here >>

Figure 2. Watershed #051401010605 around Louisville, KY

Figure 3. Land Use Change (1992~2001) in the Watershed #051401010605

Similar to the rest of the U.S., the Interior Plains has experienced rapid urbanization, and new land development is not evenly distributed. A simple regression shows the watersheds shared by a larger number of incorporated cities or towns (i.e., a higher degree of political fragmentation) are more likely to experience land development, indicated by a lower survival rate of green land areas.[3]

$$\underset{}{\textit{Survival\%}} = \underset{(0.019)}{101.196} - \underset{(0.002)}{0.313}\ \textit{Developed\%} - \underset{(0.017)}{0.102}\ \textit{NUMPL}$$

where *Survival%* is the survival rate of the grassland/shrub, agriculture, or wetlands between 1992 and 2001; *Developed%* is the percentage of developed land in each watershed in 1992; and *NUMPL* indicates the number of incorporated cities or towns that share the 12-digit watershed.

Does this finding imply that political fragmentation in local governance induces rapid development and has implications for land and water resource management? Or, is this statistically significant association attributable to other factors? The following sub-section presents a model designed to determine the influence of local governance structures (particularly, political fragmentation) in a more systematic manner, while controlling for other conditions.

3.2. Model

To examine the influence of governance structures on land use changes in the watersheds, this study focuses on changes in population and employment densities and analyzes the effect of the governance structures on these two interrelated variables at the 12-digit watershed scale. For this

[3] Here, *Survival%* and *Developed%* for all 12-digit watersheds in the Interior Plains are computed using the National Land Cover Data (NLCD) 1992/2001 Retrofit Change Product (Fry et al. 2009). *Developed%* is included to control for the fact that the survival rates are generally lower in pre-urbanized areas than the sites with abundant developable land. The estimated coefficients of all explanatory variables, including *NUMPL*, are found statistically significant at the 0.1% level. The r-squared value was 0.507.

purpose of analysis, the present study employs a disequilibrium adjustment model that has been increasingly used for a wide range of empirical analyses in which changes in population and employment (or their density levels) are investigated together with consideration of their interrelationship. As explained in Boarnet (1994), Mulligan et al. (1999), Boarnet et al. (2005), and others, the model describes population and employment changes as an adjustment process that narrows the gap between their current levels and an equilibrium point incrementally. In other words, rather than relying on a strong assumption that population and employment distributions in reality are in equilibrium, it focuses on the dynamic process of population and employment changes that can be influenced by each other as well as by other factors. Because the adjustment model is designed to deal with the interaction between population and employment changes explicitly, it has been widely used to examine whether people follow jobs or jobs follow people (see e.g., Steinnes and Fisher, 1974; Clark and Murphy, 1996; Glavac et al., 1998). In addition, since Carlino and Mills' (1987) pioneering work, the model has been extended and increasingly employed for studies on urban-suburban-rural linkages (see e.g., Henry et al. 1997, 1999, 2001) and other policy issues (see e.g., Bollinger and Ihlanfeldt, 1997; Deller et al., 2001; Mulligan and Vias, 2006), including research on sprawl and land use (Carruthers and Vias, 2005; Carruthers and Mulligan 2007), as the model is both theoretically sound and empirically powerful.

More specifically, the following system of two equations is employed by adopting de Graaff et al.'s (2012) idea of avoiding a methodological issue in the previous model applications.[4]

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[4] de Graaff et al. (2012) proposed to use the spatial lag of dependent variables (e.g., $W \cdot \Delta lnPD_{i,(t,t+1)}$ and $W \cdot \Delta lnPD_{i,(t,t+1)}$) instead of ($I$+$W$) matrices, which have "the problem

$$\Delta lnPD_{i,(t,t+1)} = G_{i,t} \cdot \alpha_P + H_{i,t} \cdot \beta_P + \rho_P \cdot W \cdot \Delta lnPD_{i,(t,t+1)} + \gamma_P \cdot \Delta lnED_{i,(t,t+1)} + \theta_P \cdot lnED_{i,t} + \lambda_P \cdot lnPD_{i,t} + \varepsilon_{P,i,t} \tag{1}$$

$$\Delta lnED_{i,(t,t+1)} = G_{i,t} \cdot \alpha_E + B_{i,t} \cdot \beta_E + \rho_E \cdot W \cdot \Delta lnED_{i,(t,t+1)} + \gamma_E \cdot \Delta lnPD_{i,(t,t+1)} + \theta_E \cdot lnPD_{i,t} + \lambda_E \cdot lnED_{i,t} + \varepsilon_{E,i,t} \tag{2}$$

where

- the two associated key variables $PD_{i,t}$ and $ED_{i,t}$ represent population and employment density levels in zone *i* (i.e., 12-digit watershed) at time *t*, respectively.
- W indicates the row-normalized spatial weight matrix included to capture the spatial lag effects over the watershed boundaries[5]; and ρ_P and ρ_E are the spatial lag parameters.
- $G_{i,t}$ is a vector of local governance (i.e., political fragmentation) variables; and α_P and α_E are the column vectors of the estimable coefficients that show the effects of

… that … [each area] and the sum of all its neighbors are, rather arbitrarily, given equal weight" (p.69)

[5] Given the large number of samples (i.e., *n*=31,485), it is computationally challenging to construct a spatial weight matrix (*W*) in a traditional manner. Therefore, in this study, neighbors for each 12-digit watershed are defined as six closest surrounding watersheds. Given the watershed boundary configuration in which most watersheds have 5~7 contiguous neighbors sharing their boundaries, this approach using the fixed number of neighbors can help generate a W matrix, which is similar to the contiguity-based spatial weight matrix, while reducing the computational burden significantly.

political fragmentation on the changes in population and employment densities. In other words, these are the parameters of interest in this land use analysis.

- $H_{i,t}$ and $B_{i,t}$ indicate a vector of exogenous variables for each dependent variable; and β_P and β_E are the column vectors of the coefficients.
- γ_P and γ_E represent scalar values that recognize the interactions of the dependent variables (i.e., the influences of population density changes on employment density changes, and vice versa).
- θ_P, θ_E, λ_P, and λ_E are the coefficients for the time lag variables. They exist in the formulation because the disequilibrium adjustment model assumes that the observed population and employment density changes are incremental adjustment from the state at *t* to the target (equilibrium) state at *t+1*.
- $\varepsilon_{P,i,t}$ and $\varepsilon_{E,i,t}$ are assumed to be independent and identically distributed errors.

This model formulation can provide methodological advantages in measuring the effects of political fragmentation on population and employment density changes that represent how land resource in each watershed is exploited. Among others, the model explains population and employment density change dynamics with explicit consideration of (potential) reciprocal interactions between the two density variables that need to be taken into account in order to precisely estimate the effects of other factors, including the characteristics of local governance structures ($G_{i,t}$). Furthermore, it is designed to capture the spillover effects involved in the process of urban development by employing a spatial weight matrix: *W*.

3.3. Variables and Data

This study utilizes multiple sources of information. To measure the population and employment density changes in the watersheds, it computes the area of developed land in individual 12-digit watersheds based on the National Land Cover Data (NLCD) 1992/2001 Retrofit Change Product provided by USGS in which high resolution land use information is presented for both 1992 and 2001 in a compatible fashion (Fry et al. 2009). Although NLCD does not work perfectly and can generate a bias in the areas where ratio of paved area to vegetative surface is relatively small (see e.g., Irwin and Bockstael, 2007), it provides detailed land cover information at a 30 × 30 meter scale for the entire conterminous U.S. More specifically, the NLCD 1992/2001 Retrofit Land Cover Change Product was recently released to enable researchers to conduct a more accurate analysis with two separately created 1992 and 2001 land cover data layers by ensuring the consistency between them. The watershed-level population and employment counts for the two measurement years are generated through areal interpolation with the use of multiple data sources, including decennial censuses (i.e., Census 1990 and 2000) and zip-code business pattern (ZBP) data.[6]

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[6] There are two notable challenges in creating the watershed-level data set based on decennial Censuses and ZBP data. First, spatial interpolation needs to be conducted to get population and employment counts for each watershed, since the original data sources are based on Census geographies or 5 digit zip-code tabulation areas. For this purpose, an areal interpolation technique, explained in Goodchild et al. (1993, p.386), is applied after overlaying the USGS 12-digit watershed shapefile with census boundary files. Second, the original data years are not perfectly matching with the study period of the present analysis: year 1992~2001. Given the year difference, the data values are adjusted (i.e., to obtain 1992 values from Census1990 data

In addition, for the governance structure variables ($G_{i,t}$), the present study employs the following three political fragmentation indicators measured at two different geographical scales (12-digit watershed scale and regional):

- *NUMPL* (12-digit watershed scale): Number of incorporated cities or towns that share each 12-digit watershed
- *PCGOV* (regional): Number of total government units per 1,000 residents in each region, which is a traditional metric widely used in a number of studies on the implications of political fragmentation, such as Hawkins and Dye (1970), Eberts and Gronberg (1988), and the empirical research discussed in section 2
- *HHI* (regional): Hirschman-Herfindahl index (that can represent the degree of political power concentration or fragmentation among government units in terms of government expenditure) employed by more recent studies, such as Grassmueck and Shields (2010), Hendrick et al. (2011), and Kim et al. (2015). For each region in which *n* local government units (denoted by $k = 1, 2, \ldots, n$) exist, the index can be calculated by summing up all units' expenditure share squares in the region, as expressed below. When the expenditure amount is equally distributed among the government units, the index value will be small with a minimum value, $1/n$. In contrast, if the expenditure is dominated by a single unit, the Hirschman-Herfindahl index is designed to have a high value with maximum=1 indicating that the entire amount of government spending is made by one entity. In other words, a higher *HHI*

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and 2001 values from Census 2000 data), using some supplementary data sets, such as annual population estimates and county business pattern data provided by U.S. Census.

value represents a less fragmented governance setting, whereas a higher value implies a more fragmented structure in the cases of *NUMPL* and *PCGOV*.

$$HHI = \sum_{k=1}^{n} \left(\frac{k^{th} \; local \; gov's \; expenditure}{Total \; gov. \; expenditure \; in \; the \; region} \right)^2$$

Consideration is also given to some additional factors which may affect the population and employment density changes. For instance, in this study, the physical size of each watershed is calculated and considered to control for the potential effect of the size on density changes, if any. A dummy variable, *NonMSA* indicating the watershed areas out of metropolitan area boundaries, is included, since the population and employment density changes in a rural context can be fundamentally different from those in a metropolitan region (see e.g., Irwin et al., 2010; Olfert and Partridge, 2010; Mockrin et al., 2013). The presence of arterial road networks are also taken into account, as population and employment density changes are often found to be affected by such transportation infrastructure conditions, particularly at a disaggregated geographical scale.

Table 1 summarizes all variables used in this analysis, including both change variables ($\Delta lnPD_{1992\sim2001}$, $\Delta lnED_{1992\sim2001}$) and initial variables ($lnPD_{1992}$, $lnED_{1992}$) and their original data sources. The descriptive statistics of the variables are presented in table 2.

<< Insert tables 1 and 2 about here >>

Table 1. Variables & Data Sources

Table 2. Descriptive Statistics

4. Analysis Results

The adjustment model (i.e., equations 1~2) is estimated with the three political fragmentation indicators – *NUMPL*, *PCGOV*, and *HHI* – by utilizing the spatial generalized moments approach (Kelejian and Robinson 1993; Kelejian and Prucha 1998 and 1999). This estimation technique is designed to address the simultaneity issues involved in the model structure that cannot be perfectly handled by ordinary least squares or traditional two-stage least squares techniques. The method constructs instrumental variables for population and employment density change rates (i.e., endogenous variables) by using independent variables and their spatial lags in order to deal with the simultaneity between the two endogenous variables. According to Rey and Boarnet (2004), this technique shows great performance in the estimation of this type of spatial cross-regressive simultaneous equation system models.

The estimation outcomes (table 3) show, among other results, that population and employment density changes are jointly determined. The population density change rates between 1992 and 2001 are found to be significantly influenced by the change rates in employment density during the same time period (the estimated coefficient: 0.714 ***), and vice versa (the estimated coefficient: 0.149 *). In other words, a strong reciprocal positive interrelationship seems to exist between 12-digit watershed scale population and employment density change rates. Furthermore, the initial levels of population and employment densities exhibit significant effects with expected signs in both equations. More precisely, the coefficients for $lnPD_{1992}$ and $lnED_{1992}$ (i.e., $lnPD_{1992}$: –0.066 *** in the population equation and $lnED_{1992}$: –0.020 ** in the employment equation) indicate that the adjustment rates (i.e., $-\lambda_P$, and $-\lambda_E$ in equations 1 and 2) fall into the appropriate range, that is between 0 and 1.

<< Insert table 3 about here >>

Table 3. Estimation Results

The positive, significant effects of the two spatial lags variables included in the model (i.e., $W \cdot \Delta lnPD_{1992\sim2001}$: 0.705 *** in the population equation and $W \cdot \Delta lnED_{1992\sim2001}$: 0.716 *** in the employment equation) indicate that the population and employment density changes in a watershed are associated with the density changes in neighboring areas – i.e., spillover effects. The magnitudes meet our expectation, falling in a range between 0 and 1. It also needs to be noted that the presence of arterial road networks has negative impacts on the area's population density change rate (–0.036 *** and –0.029 ***), while the variables turn out to be insignificant in the case of employment density changes.

Regarding the influence of local governance structures, the main focus of this study, the model estimation results appear to imply that political fragmentation does modify development patterns and thus has significant implications for resource management. More specifically, population density change rates are found to increase slowly in a fragmented watershed, indicated by the significant negative impact of *NUMPL* (–0.006 ***). The magnitude of the estimated coefficient suggests that an additional municipality involved can deter population density increases by approximately 0.6 percent between 1992 and 2001, holding all other conditions (including the employment change rate) constant.

Another variable, *PCGOV*, also exhibits a significant, negative impact (–0.004 *) on population density change rates. This finding is consistent with the previous research showing the connection between political fragmentation and sprawl at a more aggregated geographical scale. Furthermore, it highlights the importance of governance structures by showing that both site-scale (measured in terms of the number of municipalities sharing each 12-digit watershed: *NUMPL*) and regional conditions (measured in terms of the number of government units per

1000 residents in each region: *PCGOV*) seem to present a significant challenge to our watershed management practices.

The implications of political fragmentation for employment density change rates are slightly different from the effects on population density changes. Unlike population density changes, the direct effects of political fragmentation indicators appear mixed and sensitive to the measurement – while the negative coefficient of *NUMPL* (–0.002 with the p-value: 0.089 – i.e., significant at 10% level) indicates that employment densities can be lower in a fragmented context, the *PCGOV*'s positive estimate (0.003 *) implies an opposite relationship.[7] Such mixed results might be partially due to differences in measurements for political fragmentation, but more fundamentally it could be attributed to the fact that each measurement reflects different facets of political structure.

One caveat to be addressed is the presence of some outliers in the dataset. As mentioned previously, there are some 12-digit watershed areas which are shared by a large number of municipalities, including one overlapping with more than 40 jurisdictional areas. These outliers, having much higher levels of *NUMPL* than the majority of other areas, can potentially generate

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[7] It needs to be noted that the positive coefficient of *PCGOV* does not necessarily mean that employment density levels always rise more rapidly in a fragmented region. Given the presence of significant bi-directional interactions between population and employment density changes and the spatial lag effects, it can be inferred that political fragmentation can have indirect (or feedback) effects on employment density change rates via the watershed's population density change and/or via employment density shifts in its neighbors. For instance, the *PCGOV*'s direct effect on employment density can be offset by the variable's negative impact on population density that in turn can affect employment density change rates.

disturbance in the model estimation. To check the possible variation of the estimation results, a range of upper limits (in terms of *NUMPL* – e.g., Max (*NUMPL*) =3 assigns 3 to all watershed areas, shared by three or more municipalities) are imposed, and the adjustment model is estimated again. Table 4 summarizes the results of these additional rounds of analysis. As shown in the table, the significant negative impact of *NUMPL* on population density changes is detected under all levels of the upper limit. Moreover, the variable's negative coefficient on employment density change rates is found to be more significant when a more strict limit is applied.

<< Insert table 4 about here >>

Table 4. Detailed Pattern of *NUMPL* Coefficients

5. Conclusion

How can resource management be influenced by the way local governance systems are organized? Although the importance of local governance systems (and institutional arrangements more broadly) for resource management practices has been widely acknowledged, our knowledge about the effectiveness of resource management in various institutional settings is still quite limited. In an attempt to enhance our understanding of the critical implications of local governance for land and water resource management, this study focuses on political fragmentation and analyzes detailed land use changes in more than 30,000 small watersheds in the Interior Plains in relation to political fragmentation variables. This is accomplished by utilizing a disequilibrium adjustment model, in which the influences of political fragmentation on population and employment density change rates can be analyzed in a systematic manner.

The empirical analysis using multiple political fragmentation metrics and high resolution land cover data for years 1992 to 2001 suggests that population densities tend to be lower in the watersheds with a highly fragmented political structure, although employment density changes do not always show such a clear relationship. The results seem to reinforce the findings of prior empirical research on this issue, at least partially. In other words, political fragmentation might be responsible for the prevalent sprawling pattern of development and thus aggravate the fiscal, social, or environmental problems often found in sprawling U.S. metropolises.

Several limitations, however, should be noted. Density variables, analyzed in the present study to investigate how political fragmentation can affect resource management, do not always accurately represent the success or failure of resource management practices. Although population and employment density changes have utility in measuring how land resources are used and managed, these variables may oversimplify the real complexity. In addition, it is difficult to assume that a higher density can always promote public welfare, a fundamental objective of resource management. Moreover, this study does not fully uncover whether density changes can be attributed to proliferation of municipalities or the lack of cooperation between them (i.e., political inefficiency). The metrics of political fragmentation, employed in the empirical analysis of this study, may also have limitations in capturing all detailed characteristics of various forms of governance in the U.S. The real structure of politics is indeed complex both horizontally and vertically. Substantial variation also exists across states (e.g., Home rule vs. Dillon's rule states).

Nonetheless, this study provides a 12-digit watershed level analysis that extends previous research on the relationship between political fragmentation and development patterns and shows how local governance structures can affect land use patterns in small watershed areas. A lower intensity of land use found in a more fragmented governance setting deserves attention, as it may indicate that a highly fragmented structure of local governance can make it difficult to curb sprawl. Furthermore, the findings seem to suggest that political fragmentation can present a profound and multi-fold challenge to the effective management of land and water resources, while disaggregated governance settings may bring substantial benefits in other respects, such as in the provision of public services, by reflecting diverse residents' interests more closely.

This finding does not necessarily mean that a more consolidated governance setting is always warranted. Rather, it suggests that conscious efforts need to be made to address the challenges in resource management and environmental planning that often arise in a highly fragmented governance setting and to deal with demographic changes and other forces that can drive further fragmentation. One feasible approach would be enhancing the effectiveness of community-based, participatory activities while maintaining the necessary cooperation across jurisdictions, as community-based resource management can solve some limitations of technocratic and bureaucratic decision-making processes (Armitage 2005). There is no doubt that various initiatives beyond traditional administrative boundaries, such as watershed monitoring and demonstration, can also be meaningful. Admittedly, no remedy can work perfectly in every context. A great deal of attention needs to be directed to determining which actions can address the challenges to resource management and environmental planning most effectively in each context and thereby make the coupled human-natural systems more sustainable.

References

Acheson, J. M. (2006). Institutional failure in resource management. *Annual Review of Anthropology*, 35, 117-134.

Armitage, D. (2005). Adaptive capacity and community-based natural resource management. *Environmental Management*, 35(6), 703-715.

Basolo, V. (2000). City spending on economic development versus affordable housing: does inter-city competition or local politics drive decisions? *Journal of Urban Affairs*, 22(3), 317-332.

Boarnet, M. G. (1994). An empirical model of intrametropolitan population and employment growth. *Papers in Regional Science,* 73(2), 135-152.

Boarnet, M. G., Chalermpong, S., & Geho, E. (2005). Specification issues in models of population and employment growth. *Papers in Regional Science,* 84(1), 21-46.

Bollinger, C. R., & Ihlanfeldt, K. R. (1997). The impact of rapid rail transit on economic development: the case of Atlanta's MARTA. *Journal of Urban Economics*, 42(2), 179-204.

Brennan, G. & Buchanan, J. (1980). *The Power to Tax: Analytical Foundations of a Fiscal Constitution*. New York: Cambridge University Press.

Brody, S. D. (2003). Implementing the principles of ecosystem management through local land use planning. *Population and Environment*, 24(6), 511-540.

Byun, P. & Esparza, A. X. (2005). A revisionist model of suburbanization and sprawl: The role of political fragmentation, growth control, and spillovers. *Journal of Planning Education and Research,* 24(3), 252–264.

Carlino, G. A. & Mills, E. S. (1987). The determinants of county growth. *Journal of Regional Science,* 27(1), 39-54.

Carruthers, J. I. (2003). Growth at the fringe: The influence of political fragmentation in United States metropolitan areas. *Papers in Regional Science,* 82(4), 475–499.

Carruthers, J. I., & Vias, A. C. (2005). Urban, suburban, and exurban sprawl in the Rocky Mountain West: Evidence from regional adjustment models. *Journal of Regional Science*, 45(1), 21-48.

Carruthers, J. I. & & Mulligan, G. F. (2007). Land absorption in U.S. metropolitan areas: Estimates and projections from regional adjustment models. *Geographical Analysis,* 39(1), 78-104.

Carruthers, J. I. & Ulfarsson, G. F. (2002). Fragmentation and sprawl: Evidence from interregional analysis. *Growth and Change,* 33(3), 312–340.

Clark, D. E., & Murphy, C. A. (1996). Countywide employment and population growth: An analysis of the 1980s. *Journal of Regional Science*, 36(2), 235-256.

de Graaff, T., van Oort, F. G., & Florax, R. J. (2012). Regional population–employment dynamics across different sectors of the economy. *Journal of Regional Science*, 52(1), 60-84.

Deller, S. C., & Rudnicki, E. (1992). Managerial efficiency in local government: Implications on jurisdictional consolidation. *Public Choice*, *74*(2), 221-231.

Deller, S. C., Tsai, T. H. S., Marcouiller, D. W., & English, D. B. (2001). The role of amenities and quality of life in rural economic growth. *American Journal of Agricultural Economics*, 83(2), 352-365.

Dreier, P., Mollenkopf, J., & Swanstrom, T. (2001). *Place Matters: Metropolitics for the 21st Century*. Lawrence: University Press of Kansas.

Eberts, R. & Gronberg, T. (1988). Can competition among local governments constrain government spending? *Economic Review – Federal Reserve Bank of Cleveland,* 24(1), 2-9.

Forbes, K. F., & Zampelli, E. M. (1989). Is Leviathan a mythical beast? *The American Economic Review,* 79(3), 568-577.

Fry, J. A., Coan, M. J., Homer, C. G., Meyer, D. K., & Wickham, J. D., (2009). Completion of the National Land Cover Database (NLCD) 1992–2001 Land Cover Change Retrofit Product. U.S. Geological Survey Open-File Report 2008–1379 http://pubs.usgs.gov/of/2008/1379/ Cited 15 Mar 2013

Glavac, S. M., Vias, A. C., & Mulligan, G. F. (1998). Population and employment interactions in the growth of United States micropolitan centers. *Urban Geography*, 19(7), 632-656.

Goodchild, M. F., Anselin, L., & Deichmann, U. (1993). A framework for the areal interpolation of socioeconomic data. *Environment and Planning A*, 25(3), 383-397.

Grassmueck, G. & Shields, M. (2010). Does government fragmentation enhance or hinder metropolitan economic growth? *Papers in Regional Science,* 89(3), 641-657.

Hardin, G. (1968). The tragedy of the commons. *Science*, 162, 1243-1248.

Hawkins, B. & Dye, T. (1970). Metropolitan fragmentation: A research note. *American Review of Public Administration,* 4(1), 17-24.

Hendrick, R. M., Jimenez, B. S., & Lal, K. (2011). Does local government fragmentation reduce local spending? *Urban Affairs Review,* 47(4), 467-510.

Henry, M. S., Barkley, D. L., & Bao, S. (1997). The hinterland's stake in metropolitan growth: Evidence from selected southern regions. *Journal of Regional Science*, 37(3), 479-501.

Henry, M. S., Schmitt, B., Kristensen, K., Barkley, D. L., & Bao, S. (1999). Extending Carlino-Mills models to examine urban size and growth impacts on proximate rural areas. *Growth and Change*, 30(4), 526-548.

Henry, M. S., Schmitt, B., & Piguet, V. (2001). Spatial econometric models for simultaneous systems: Application to rural community growth in France. *International Regional Science Review*, 24(2), 171-193.

Hutson, M. A., Kaplan, G. A., Ranjit, N., & Mujahid, M. S. (2012). Metropolitan fragmentation and health disparities: Is there a link?. *Milbank Quarterly*, 90(1), 187-207.

Irwin, E. G., & Bockstael, N. E. (2007). The evolution of urban sprawl: Evidence of spatial heterogeneity and increasing land fragmentation. *Proceedings of the National Academy of Sciences*, *104*(52), 20672-20677.

Irwin, E. G., Isserman, A. M., Kilkenny, M., & Partridge, M. D. (2010). A century of research on rural development and regional issues. *American Journal of Agricultural Economics*, 92(2), 522-553.

Kauneckis, D., & Andersson, K. (2009). Making decentralization work: A cross-national examination of local governments and natural resource governance in Latin America. *Studies in Comparative International Development*, 44(1), 23-46.

Kelejian, H. H. & Prucha, I. R. (1998). A generalized spatial two-stage least squares procedure for estimating a spatial autoregressive model with autoregressive disturbances. *Journal of Real Estate Finance and Economics,* 17(1), 99–121.
Kelejian, H. H. & Prucha, I. R. (1999). A generalized moments estimator for the autoregressive parameter in a spatial model. *International economic review,* 40(2), 509–533.
Kelejian, H. H. & Robinson, D. P. (1993). A suggested method of estimation for spatial interdependent models with autocorrelated errors, and an application to a county expenditure model. *Papers in Regional Science,* 72(3), 297–312.
Kim, J. H., & Hewings, G. J. (2012). Integrating the fragmented regional and subregional socioeconomic forecasting and analysis: a spatial regional econometric input–output framework. *Annals of Regional Science*, 49(2), 485-513.
Kim, J. H., & Hewings, G. J. D. (2013). Interjurisdictional competition and land development: A micro-level analysis. In F. Pagliara, M. de Bok, D. Simmonds, & A.G. Wilson (Ed.), *Employment location in cities and regions: Models and applications* (pp.181-199). Heidelberg: Springer.
Kim, J. H., & Jurey, N. (2013). Local and regional governance structures: Fiscal, economic, equity, and environmental outcomes. *Journal of Planning Literature*, 28(2), 111-123.
Kim, J. H., Keane, T. D., & Bernard, E. A. (2015). Fragmented local governance and water resource management outcomes. *Journal of Environmental Management*, 150, 378-386.
Knight, K. W., & Rosa, E. A. (2012). Household dynamics and fuelwood consumption in developing countries: A cross-national analysis. *Population and Environment*, 33(4), 365-378.
Kunce, M., & Shogren, J. F. (2005). On interjurisdictional competition and environmental federalism. *Journal of Environmental Economics and Management*, 50(1), 212-224.
Lewis, P. G. (1996). *Shaping suburbia: How political institutions organize urban development*. Pittsburgh, PA: University of Pittsburgh Press.
Mockrin, M. H., Stewart, S. I., Radeloff, V. C., Hammer, R. B., & Johnson, K. M. (2013). Spatial and temporal residential density patterns from 1940 to 2000 in and around the Northern Forest of the Northeastern United States. *Population and Environment*, 34(3), 400-419.
Morgan, D. R., & Mareschal, P. (1999). Central-city/suburban inequality and metropolitan political fragmentation. *Urban Affairs Review*, 34(4), 578-595.
Mulligan, G. F., & Vias, A. C. (2006). Growth and change in US micropolitan areas. *Annals of Regional Science*, 40(2), 203-228.
Mulligan, G. F., Vias, A. C. & Glavac, S. M. (1999). Initial diagnostics of a regional adjustment model. *Environment and Planning A*, 31(5), 855-876.
Nagendra, H., & Ostrom, E. (2012). Polycentric governance of multifunctional forested landscapes. *International Journal of the Commons*, *6*(2), 104-133.
Neef, A. (2009). Transforming rural water governance: Towards deliberative and polycentric models. *Water Alternatives*, *2*(1), 53-60.
Olfert, M., & Partridge, M. D. (2010). Best practices in twenty-first-century rural development and policy. *Growth and Change*, 41(2), 147-164.
Ostrom, E.(1990). *Governing the commons: The evolution of institutions for collective action*. Cambridge: Cambridge University Press.
Ostrom, E. (1999). Coping with tragedies of the commons. *Annual review of political science*, 2(1), 493-535.

Ostrom, E. (2000). Collective action and the evolution of social norms. *Journal of Economic Perspectives*, 14(3), 137-158.
Ostrom, E., Burger, J., Field, C. B., Norgaard, R. B., & Policansky, D. (1999). Revisiting the commons: Local lessons, global challenges. *Science*, *284*(5412), 278-282.
Pendall, R. (1999). Do land-use controls cause sprawl? *Environment and Planning B: Planning and Design*, 26(4), 555-571.
Peterson, P. E. (1981). *City Limits*. Chicago: University of Chicago Press.
Razin, E. & Rosentraub, M. (2000). Are fragmentation and sprawl interlinked? North American evidence. *Urban Affairs Review,* 35(6), 821-836.
Rey S. J. & Boarnet, M. G. (2004). A taxonomy of spatial econometric models for simultaneous equations systems. In L. Anselin, R. Florax, & S. J. Rey (Ed.), *Advances in spatial econometrics: Methodology, tools, and applications* (pp.99-119). Berlin: Springer.
Rodrik, D. (2004). Getting institutions right. *CESifo DICE Report*, 2(2004), 10-15.
Savitch, H. V., & Vogel, R. K. (2004). Suburbs without a city power and city-county consolidation. *Urban Affairs Review*, 39(6), 758-790.
Shen, Q. (1996). Spatial impacts of locally enacted growth controls: the San Francisco Bay Region in the 1980s. *Environment and Planning B*, 23(1), 61-91.
Sherval, M., & Askew, L. E. (2012). Experiencing 'drought and more': Local responses from rural Victoria, Australia. *Population and Environment*, 33(4), 347-364.
Steinnes, D. N., & Fisher, W. D. (1974). An econometric model of intraurban location. *Journal of Regional Science*, 14(1), 65-80.
Stroup, R. L. (1991). Controlling earth's resources: Markets or socialism? *Population and Environment*, 12(3), 265-284.
Tiebout, C. M. (1956). A pure theory of local expenditures. *Journal of Political Economy,* 64(5), 416–424.
Ulfarsson, G. F. & Carruthers, J. I. (2006). The cycle of fragmentation and sprawl: A conceptual framework and empirical model. *Environment and Planning B: Planning and Design,* 33(5), 767–788.
Weiher, G. R. (1991). *The Fractured Metropolis: Political Fragmentation and Metropolitan Segregation*. Albany, NY: SUNY Press.
Yaffee, S. L. (1997). Why environmental policy nightmares recur. *Conservation Biology*, 11(2), 328-337.

Table 1. Variables & Data Sources

Variables	Description	Data Sources
$\Delta lnPD_{1992\sim2001}$	Log of population density change rates, 1992~2001	DC [a], APE [b], Census-BF [c], USDA-WBD [d], NLCD [g]
$\Delta lnED_{1992\sim2001}$	Log of employment density change rates, 1992~2001	ZBP [e], CBP [f], Census-BF, USDA-WBD, NLCD
$lnPD_{1992}$	Log of population density in 1992	DC, APE, Census-BF, USDA-WBD, NLCD
$lnED_{1992}$	Log of employment density in 1992	ZBP, CBP, Census-BF, USDA-WBD, NLCD
$lnTOTACRE$	Log of watershed size (in acre)	USDA-WBD
$NonMSA$	Dummy for non-MSA areas	Census-BF, USDA-WBD
$RoadFC1$	Dummy indicating the presence of interstate highways	NHPN [h], USDA-WBD
$RoadFC2$	Dummy indicating the presence of other expressways	NHPN, USDA-WBD
$NUMPL$	Number of the intersected municipalities in each 12-digit watershed	Census-BF, USDA-WBD
$PCGOV$	Number of total government units per 1000 residents in each region	CoGov [i]
HHI	Hirschman-Herfindahl index calculated based on the total expenditure distribution among the government units in each region	CoGov

[a] Decennial Census, US Census Bureau | [b] Annual population estimates, US Census Bureau | [c] Census Boundary Files, US Census Bureau
[d] USDA Watershed Boundary Dataset, US Department of Agriculture | [e] Zip code business pattern data, US Census Bureau
[f] County business pattern data, US Census Bureau | [g] National Land Cover Data 1992/2001 Retrofit Change Product, US Geological Survey
[h] National Highway Planning Network data | [i] Census of Governments 1992, US Census Bureau

Table 2. Descriptive Statistics

Variables	Mean	Stdev	Min	Max
$\Delta lnPD_{1992\sim2001}$	0.071	0.322	-3.440	5.090
$\Delta lnED_{1992\sim2001}$	0.095	0.223	-2.690	4.360
$lnPD_{1992}$	-0.267	1.297	-2.280	6.080
$lnED_{1992}$	-1.102	1.227	-2.300	7.510
$lnTOTACRE$	9.997	0.423	3.230	12.970
$NonMSA$	0.819	0.385	0.000	1.000
$RoadFC1$	0.123	0.328	0.000	1.000
$RoadFC2$	0.325	0.468	0.000	1.000
$NUMPL$	0.633	1.219	0.000	44.000
$PCGOV$	1.718	1.527	0.060	6.590
HHI	0.030	0.058	0.003	0.500

Table 3. Estimation Results

Variable	Description	Pop. Density Eq. : on $\Delta lnPD_{1992\sim2001}$		Emp. Density Eq.: on $\Delta lnED_{1992\sim2001}$	
		Estimated Coefficient	**Standard Error**	**Estimated Coefficient**	**Standard Error**
C	Intercept	0.029	0.048	0.052	0.027
$W \cdot \Delta lnPD_{1992\sim2001}$	Spatial lag of pop. density change rates (logged)	0.705 ***	0.087		
$W \cdot \Delta lnED_{1992\sim2001}$	Spatial lag of emp. density change rates (logged)			0.716 ***	0.091
$\Delta lnPD_{1992\sim2001}$	Pop. density change rates (logged)			0.149 *	0.068
$\Delta lnED_{1992\sim2001}$	Emp. density change rates (logged)	0.714 ***	0.127		
$lnPD_{1992}$	Population density in 1992 (logged)	-0.066 ***	0.004	0.024 ***	0.005
$lnED_{1992}$	Employment density in 1992 (logged)	0.068 ***	0.005	-0.020 **	0.007
$lnTOTACRE$	Watershed size (logged)	-0.003	0.005	-0.003	0.003
$NonMSA$	Non-MSA areas	0.043 **	0.014	-0.029 ***	0.008
$RoadFC1$	Presence of interstate highways	-0.036 ***	0.006	0.005	0.005
$RoadFC2$	Presence of other expressways	-0.029 ***	0.004	0.005	0.004
$NUMPL$	Number of municipalities sharing the watershed	-0.006 ***	0.002	-0.002	0.002
$PCGOV$	Number of gov. units per 1000 residents in the region	-0.004 *	0.002	0.003 *	0.001
HHI	Hirschman-Herfindahl index	0.069	0.050	-0.057	0.032
R-squared		0.337		0.484	
Adj. R-squared		0.337		0.483	

***: 0.1% level, **: 1% level, *: 5% level significant

Table 4. Detailed Pattern of *NUMPL* Coefficients

Upper Limit	**Pop. Density Eq.: on $\Delta lnPD_{1992\sim2001}$**		**Emp. Density Eq.: on $\Delta lnED_{1992\sim2001}$**	
	Estimated Coefficient	**Standard Error**	**Estimated Coefficient**	**Standard Error**
Max (NUMPL) = 3	-0.015 ***	0.003	-0.007 *	0.003
Max (NUMPL) = 4	-0.013 ***	0.003	-0.006 *	0.003
Max (NUMPL) = 5	-0.012 ***	0.003	-0.005	0.003
Max (NUMPL) = 6	-0.011 ***	0.002	-0.004	0.003
Max (NUMPL) = 7	-0.010 ***	0.002	-0.004	0.002
Max (NUMPL) = 8	-0.010 ***	0.002	-0.003	0.002
Max (NUMPL) = 9	-0.009 ***	0.002	-0.003	0.002
Max (NUMPL) = 10	-0.009 ***	0.002	-0.003	0.002
No Limit	-0.006 ***	0.002	-0.002	0.002

***: 0.1% level, **: 1% level, *: 5% level significant

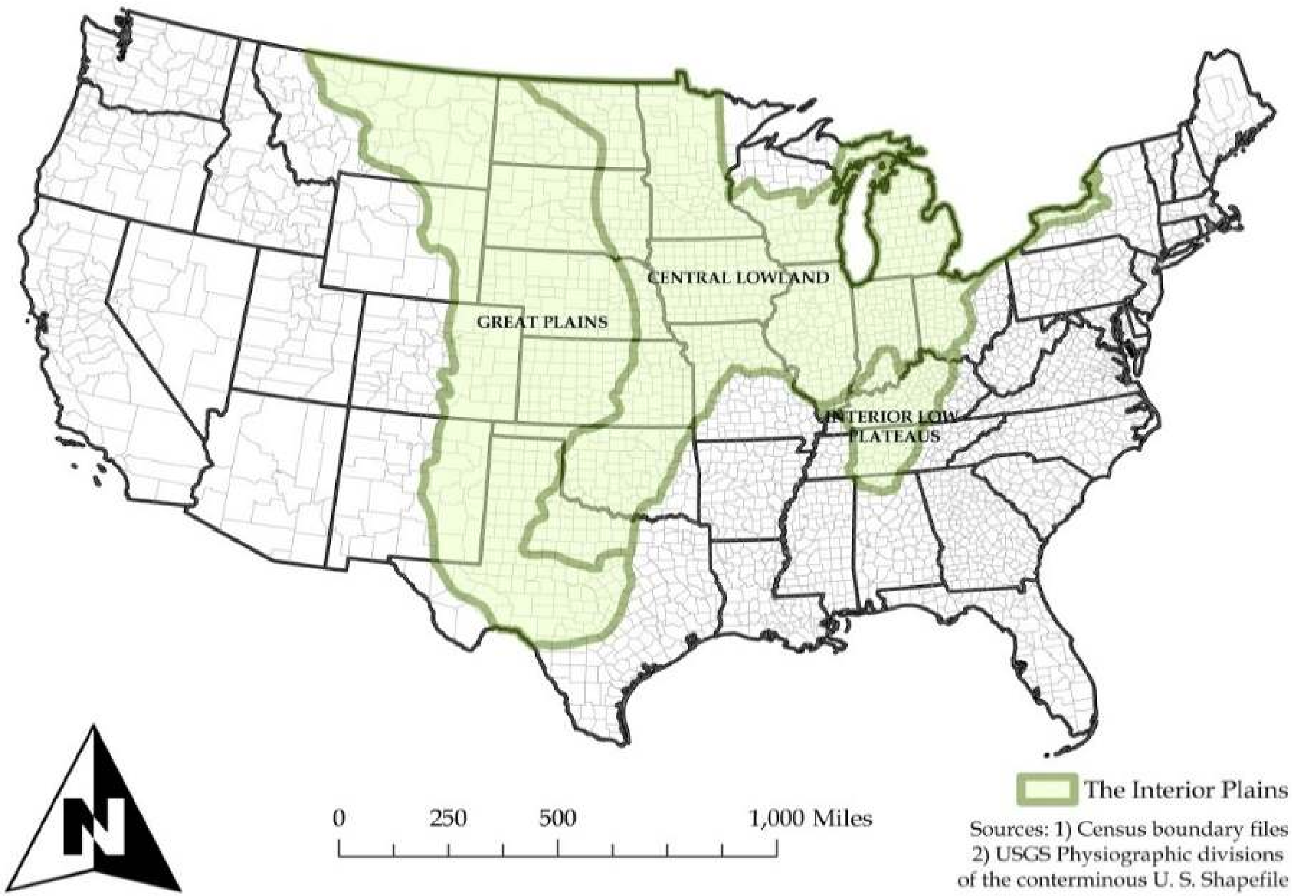

Figure 1. Study Area: The Interior Plains

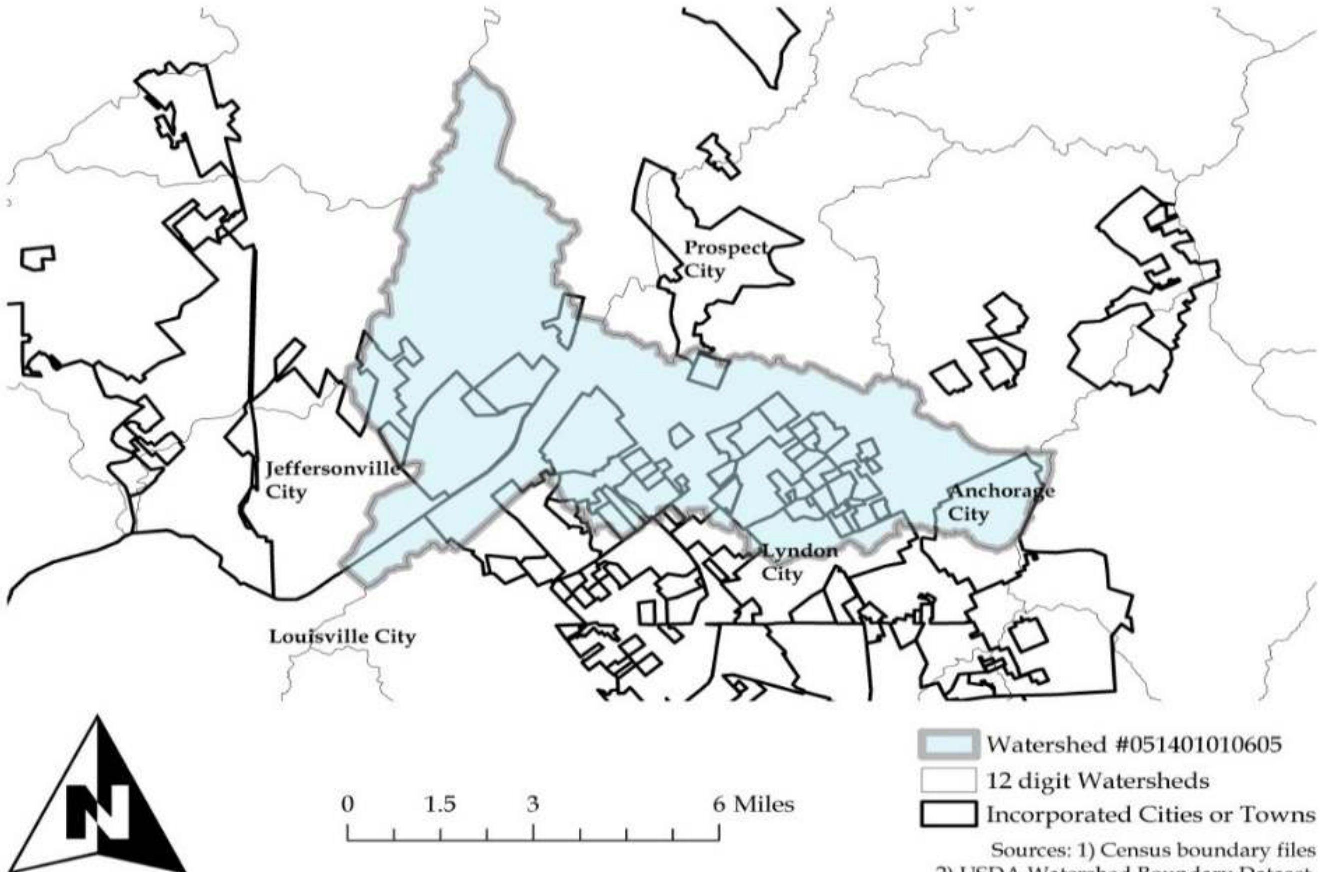

Figure 2. Watershed #051401010605 around Louisville, KY

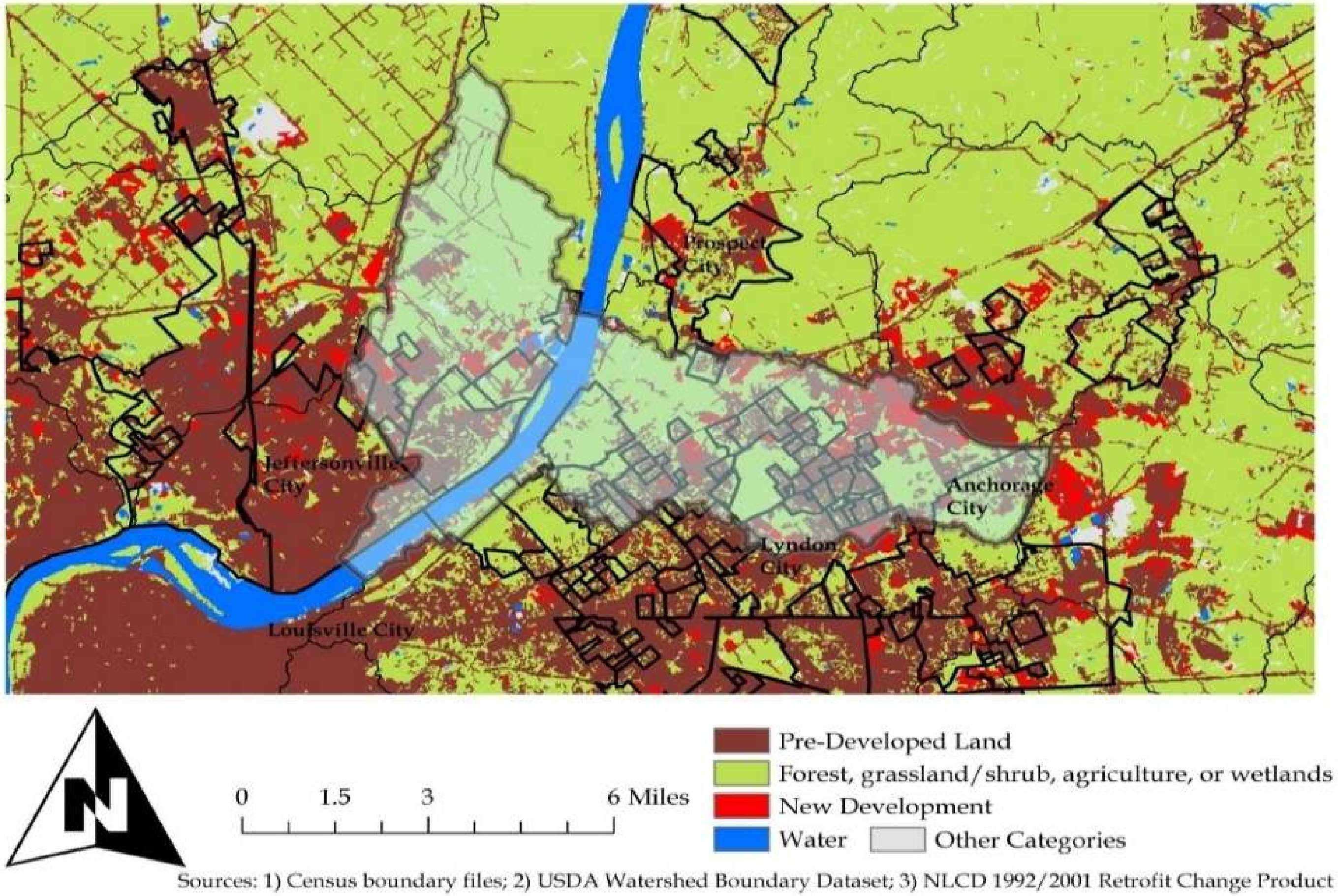

Figure 3. Land Use Change (1992~2001) in the Watershed #051401010605