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Assessing the Impacts of Streamside Ordinance Protection on the Spatial and Temporal Variability in Urban Riparian Vegetation

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Abstract: Preserving riparian vegetation is important for maintaining water quality and riparian functions. Streamside protection ordinances have been widely established in many rapidly urbanizing areas, however, there has been a lack of assessment of the effectiveness of such ordinances. A study was conducted to determine the effectiveness of riparian vegetation preservation with and without ordinance protection. SPOT imagery was used to classify landscape changes over time (1992 through 2012) across multiple jurisdictions and pre- and post-ordinance implementation periods. Results indicated the spatial and temporal patterns of vegetation change differed by administrative areas and ordinance boundaries. The rate of tree loss and gains in developed lands in ordinance-protected areas generally increased following implementation of ordinances but at a lower rate than in non-ordinance areas. These findings suggest spatial and temporal monitoring of riparian ordinance implementation across adjacent jurisdictions is important to ensure the full effects of the ordinance protection on stream systems. Such monitoring and assessments can be used by local decision makers to adapt existing ordinances or in the development of new ordinances.

Keywords: urban riparian areas; streamside ordinances; riparian vegetation; satellite imagery; riparian protection

1. Introduction

Riparian areas are the terrestrial lands adjacent to rivers, streams, or lakes that encompass the transition between these aquatic features and the adjacent uplands [1–4]. Riparian areas serve many ecological functions including natural filtering of runoff pollutants [5], detaining or retaining runoff and flood flows [6], providing stream temperature control [7], and serving as wildlife habitats [2,8]. Restoration and maintenance of riparian areas has been presented as effective practices in the management of non-point source runoff [9]. Despite these proven benefits, the loss and degradation of riparian areas continues, particularly because of urbanization [10], which has prompted this study of assessing the effectiveness of riparian ordinance implementation.

Urbanization results in the loss and degradation of riparian areas and in changes in the composition of riparian vegetation [10,11]. Vegetation loss and riparian area degradation in urbanizing area are largely the result of the development of infrastructure related to transportation, flood-management efforts, and activities to facilitate runoff [4,12]. Riparian vegetation in urban settings can also be negatively affected by secondary factors resulting in increased overland flow and the retention of sediment and pollutants from the surrounding urban landscape [13]. In terms of the driving factors for vegetation loss in urban settings, the rate and timing of vegetation change has commonly been correlated with multiple socioeconomic factors. Pickett et al. [14] found a correlation, albeit lagged, between the temporal change in household income and vegetation change in the Baltimore, MD area. Luck examined the correlation between urban vegetation change and various socio-economic factors in southeast Australia (1991–2006) including income, housing density, and education [15]. Population change, development of infrastructure, local government policy, and socio-economic factors are among the driving forces in land-use land-cover modeling [16]. These studies utilized data from remote sensing because it provided a repetitive and synoptic coverage of the areas analyzed.

In the United States, rivers and wetlands were awarded Federal protection from discharge of dredged and fill materials and pollutants beginning in 1972 with the Federal Water Pollution Control Act (Section 404, Clean Water Act, [2]). This act, however, does not extend protection to adjacent riparian areas. As such, riparian areas have been left unprotected by Federal regulations. The US Environmental Protection Agency provides model regulatory resource-protection ordinances that local and state governments can voluntarily adopt for the protection of aquatic resources and control of erosion and urban runoff [17]. International approaches to riparian protection vary greatly. For example, there tends to be less riparian forest protection in countries with market economies, including the United States and Western European countries, compared to Central and Eastern European countries associated with the former Soviet Union [18].

In the United States, studies of stream vegetation buffers have primarily focused on the functional effectiveness and design of buffers for controlling erosion [1,8,11,19], water quality issues [8,11,20], and habitat loss [2,21,22]. Limited research, however, has been conducted documenting the performance of streamside ordinances after implementation, including the effectiveness of the ordinances in maintaining the natural vegetation cover over time. Ozawa and Yeakley [23] and Yeakley et al. [24] studied the performance of streamside ordinances and the protection of riparian vegetation in the metropolitan area of Portland, Oregon, USA. Their study incorporated all streams from three cities around Portland that had riparian buffer ordinances using aerial imagery from 1990, 1997, and 2002. The streamside ordinances in the study cities were evolving and being implemented during the analysis period. The three years of satellite imagery used in the analyses did not correspond to pre- and post-ordinance periods, which makes it difficult to isolate the effectiveness of the streamside ordinances, or to see the causal influence of the ordinance on the rate of land-cover change.

To address the lack of riparian protection assessments, a study was conducted to document vegetation change along an urban river system that flows through multiple jurisdictions and determine the effectiveness of streamside ordinances in maintaining the existing riparian vegetation during a 20-year period. Specific study objectives of the study were to (1) quantify the temporal (1992, 2003, 2009, 2012) changes in land cover including riparian vegetation along an urban river system and (2) to assess the variation in land-cover changes by state and local administrative boundaries before and after the enactment of stream-side protection ordinances as well as within protected and unprotected areas.

The study area includes selected riparian areas located in the Blue River Basin (725 km^2) in the Kansas City metropolitan area, USA (Figure 1). The Kansas City metropolitan area includes two states (west-central Missouri, east-central Kansas), and multiple counties and municipal jurisdictions within a similar ecological and environmental setting. The study area includes 33.14 km^2, of which 27.31 km^2 is in Missouri and 5.83 km^2 is in Kansas (Table 1), and represents various conditions of riparian protection. The Missouri portion of the study area contains streamside-ordinance protection areas (buffer zones) and non-ordinance protected areas along the Blue River in Kansas City, MO, USA (Figure 1). The Kansas portion of the study area includes a streamside-protected area of the Blue River within the city of Overland Park, as well as areas without streamside ordinance protection within the city of Overland Park, and unincorporated portions of Johnson County, KS, USA. The study area primarily is located in the wooded Osage Plains ecoregion [25] and the natural vegetation included a mosaic of oak-hickory woodland and bluestem prairie. The current vegetation is a mosaic of woodland (oak-hickory), cropland, and grassland.

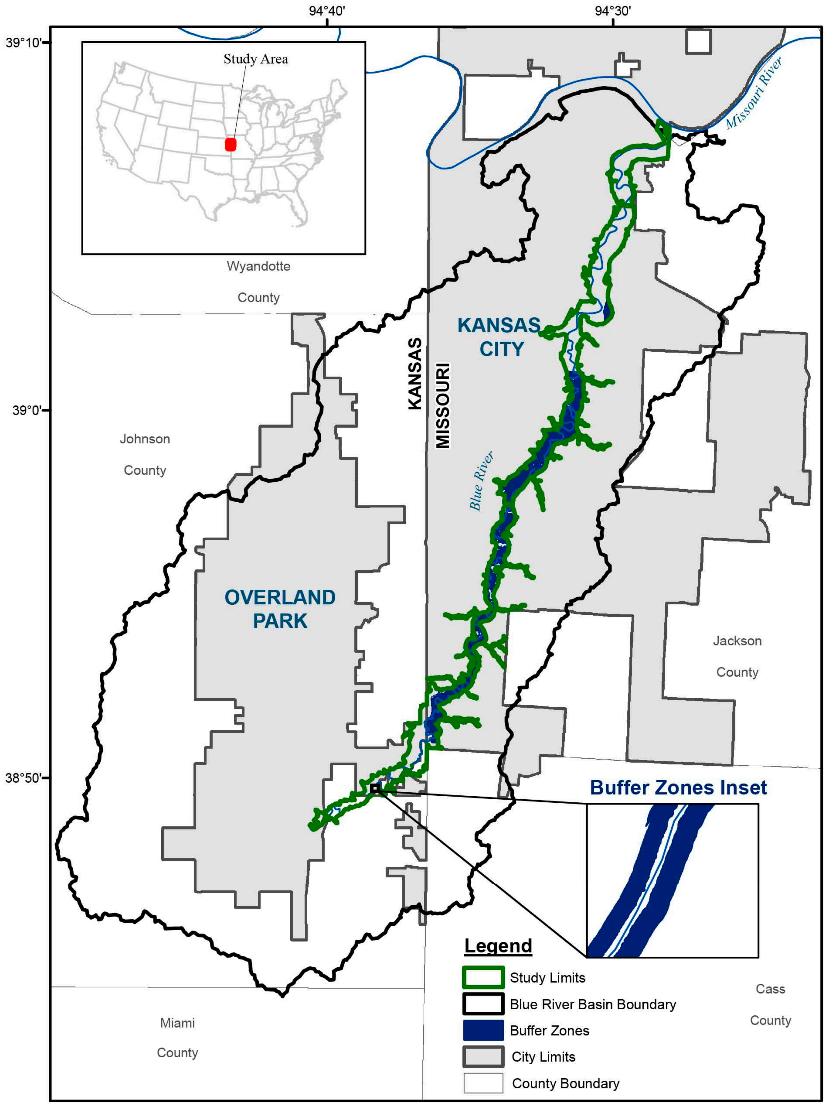

Figure 1. Kansas City Metropolitan Area USA and Blue River Basin.

Table 1. Area distribution of the jurisdictional boundaries within the study area and the current status of streamside ordinances.

State	Administrative Area	Area (km^2)	Ordinance	Date Enacted
Kansas	Overland Park	0.52	YES	7 October 2002
Kansas	Overland Park (Outside ordinance zone)	3.24	NO	
Kansas	Unincorporated Johnson County	2.07	NO	
Missouri	Kansas City	13.73	YES	14 February 2009
Missouri	Kansas City (Outside ordinance zone)	13.58	NO	
Total Area (Area within ordinance zone/Area outside ordinance zone)		33.14 (14.25/18.89)		

2. Materials and Methods

2.1. Defined Riparian Area

Riparian areas do not have absolute boundaries, so a contiguous study area boundary was methodically developed. The riparian area limits were defined by multiple digital data sources reflecting the hydrologic interaction of the river and its floodplain. The riparian area perimeter included (1) the extent of the estimated 1-percent annual exceedance probability streamflow (100-year recurrence interval flood; [26]), (2) the hydric soils layer [27], (3) a 33-m offset from the top-of-bank extracted from a lidar-derived digital terrain model of the Blue River Basin [26], (4) a wetlands layer [28], and (5) the defined city of Kansas City streamside buffer protection extent [29]. The final area boundary was defined by the exterior maximum lateral extent of the multiple composite features. Using ArcGIS 10.5, the boundary layer was smoothed and interpolated to remove map feature islands that were smaller than 3 m^2 in the select areas for which datasets were incomplete.

2.2. Streamside Ordinances

The temporal scope of the study was the 20-year period from 1992–2012 and included a pre-ordinance (1992–2009) and post-ordinance (2009–2012) period for Kansas City, MO, USA, and a pre-ordinance (1992–2002) and post-ordinance (2003–2012) period for Overland Park, KS, USA. The city of Kansas City passed a stream buffer ordinance in 2008 and implemented the ordinance on 14 February 2009 [30]. The streamside ordinances were written with the purposes of helping to protect life and property, preventing flooding, preserving water quality, and conserving wildlife habitat (KCMO 88-415). The ordinance does not limit any flood control activities. The city of Overland Park passed a streamside ordinance in 2002 and implemented it on 7 October 2002 [31]. Overland Park implemented a one-zone variable buffer area based on the acreage of the tributary area of the stream. The maximum buffer zone offset is 36.6 m for a 20.2 km^2 or greater drainage area, which is the category that includes the Blue River in Overland Park. The buffer starts at the top of bank and extends the specified distance on each side of the stream to create a protection zone. The ordinance restricts the building of permanent structures but allows for exceptions when changes made are a result of flood mitigation efforts. The ordinance also permits agricultural uses, recreational uses, limited golf course uses, and permits tree trimming, but restricts vegetation destruction [31]. The Blue River riparian corridor within the unincorporated area of Johnson County, KS, USA, was not within a designated streamside ordinance protection zone throughout the study period. This area provided an additional portion of the Blue River outside of any ordinance zone to use as a control for non-ordinance protection condition.

2.3. Description of Imagery and Processing

The satellite imagery that was selected was from the Satellite Pour l'Observation de la Terre (SPOT). SPOT images acquired in 1992, 2003, 2009, and 2012 [32] were used in this study to determine land-cover and land-use change over a 20-year period. The earliest image (1992) was selected based on availability and the objective to define a pre-ordinance reference condition. ERDAS Imagine 2013 software was used to pre-process, classify, and assess the accuracy of the classifications. Initial geo-rectification was required of the SPOT imagery. The spatial resolution of the 1992 and 2003 imagery was 20 m, and that of the 2009 and 2012 imagery was 10 m. Image resampling was conducted on the 2009 and 2012 imagery to obtain a consistent 20-m resolution for all imagery. The SPOT imagery was used for analysis rather than products with greater observational density (e.g., Landsat imagery) because of their greater spatial resolution.

Supervised maximum likelihood classification [33,34] was conducted on the four images based on a modified US Geological Survey (USGS) land cover classification system [35]. The maximum likelihood classification method assigns equal prior probability of a pixel belonging to a class, and then the pixel was assigned to the class with the highest probability [34]. The images were classified into five land-cover classes including barren land, developed land, grasses, trees, and water. Barren land was defined as disturbed or bare earth lands. Developed land included any type of urban development, roads, or build up. The grasses category also included agricultural lands (pasture, rangeland) or cropland. The trees classification represented a class that predominately contains woody vegetation. The water class included all rivers, lakes, streams, ditches, or manmade reservoirs that were large enough to be represented at the 20-m scale. This classification system was used to simplify land-use and land-cover in a complex urban landscape while retaining the land cover of primary interest for the study. The classified SPOT images were checked for accuracy by assigning 250 randomly stratified ground truth points to each classified image and matching these against corresponding high-resolution imagery [36] acquired in, or near (within 24 months), the acquisition year of the SPOT imagery. Then, the User's and Producer's accuracies as well as the overall accuracy for each classified image were calculated [34,37]. The User's accuracy corresponds to the error of commission, i.e., pixels from the classified imagery erroneously included in the land-cover class under consideration, while the Producer's accuracy represents the error of omission meaning the pixels from the classified imagery erroneously omitted from the class under consideration.

2.4. Data Analysis

The defined riparian area was subdivided by state and municipal boundaries as well as by ordinance protection areas using ArcGIS 10.5. The Missouri portion of the study area, entirely within the city of Kansas City was separated into two regions. The first region was clipped to the city of Kansas City stream buffer zones and included both pre- and post-ordinance periods, and the second region represented the area that was outside of the stream buffer zones, representing a non-ordinance protected area or control. The study area in Kansas was divided into two separate regions including one containing the ordinance protected areas located entirely within the city of Overland Park, and the other covering the area outside of Overland Park—the non-ordinance area referred to as un-incorporated Johnson County. The area within Overland Park was further divided into two regions—the area with stream ordinance protection including both a pre-ordinance and post-ordinance period and the non-ordinance protected area.

The city of Overland Park designates the ordinance zone by means of drainage area and a corresponding buffer protection zone. A streams data layer [38] was used to select the Blue River and Negro Creek Basins within the study boundary area within Overland Park. These two streams were determined to have stream tributary areas greater than or equal to 20.2 km^2, corresponding to the maximum ordinance protection of 36.6 m [31]. The elevation contour lines derived from a Blue River Basin terrain model [26] were used to delineate the high-water mark extents. The high-water marks were buffered by the ordinance buffer width to create the extents of the protected area. The extents were used to define the buffered protection layer and the remaining unprotected study areas in Overland Park. The resulting seven state-municipal-ordinance defined study area extents then were converted to raster files.

The total and annualized rate of change for each classification category were determined by municipality, pre-post-ordinance periods, and by ordinance zones. The raster files of the study extent were used to extract the land use-land-cover categories for each of the four classified images. The land-cover values, extracted by state-municipal-ordinance boundaries, provided discrete land-cover sampling points corresponding to the year of imagery. The land-cover classes within the study limits were determined for the pre- and post-ordinance periods defined using the available SPOT images (1992, 2003, 2009, and 2012). The quantitative changes in the land-cover classes were divided by the years between image dates to determine the land-cover values per study boundary type per year.

3. Results

The image classification accuracies were considered satisfactory for the purpose of our study, which identified the patterns and trends of related land-cover changes. The overall accuracy was 88% for the 1992 imagery, 90% for 2003, 92% for 2009, and 91% for the 2012 imagery (Table 2). The User's and Producer's accuracies were in the 80–90 percentage range for the trees and grasses land-cover.

3.1. Total Riparian Vegetation Change within the Study Area

The study area showed a net loss in trees and grasses from 1992 to 2012 and a corresponding increase in developed land-cover during the same period (Table 3). The trees land-cover class had a net decrease of approximately 12.5% or 4.15 km^2 over the 20-year period and indicated a consistent incremental loss of trees for each image analysis period. Similarly, the grasses land-cover class lost 9.6% or 3.2 km^2 between 1992 and 2012 within the study area. The greatest change in the land-cover classes occurred in developed land, which increased by 22.86% and 7.57 km^2 between 1992 and 2012. The net increase in developed land also was consistent in each discrete analysis increment over the 20-year study period. There was little (<2%) net change in the barren land and water land-cover categories over the 20-year study period.

Table 2. Accuracy assessment of the Satellite Pour l'Observation de la Terre (SPOT) imagery classifications.

1992 Accuracy Assessment			2009 Accuracy Assessment		
Class Name	**Producer's Accuracy**	**User's Accuracy**	**Class Name**	**Producer's Accuracy**	**User's Accuracy**
Barren Land	71.40%	83.33%	Barren Land	87.50%	82.35%
Grasses	90.91%	87.91%	Grasses	92.16%	92.16%
Trees	89.19%	88.39%	Trees	96.15%	93.46%
Urban Land	84.62%	86.84%	Urban Land	92.00%	94.52%
Water	72.73%	88.89%	Water	70.00%	87.50%
Overall Classification Accuracy	87.89%		Overall Classification Accuracy	92.58%	
2003 Accuracy Assessment			**2012 Accuracy Assessment**		
Class Name	**Producer's Accuracy**	**User's Accuracy**	**Class Name**	**Producer's Accuracy**	**User's Accuracy**
Barren Land	72.73%	88.89%	Barren Land	80.00%	88.89%
Grasses	85.07%	90.48%	Grasses	88.00%	93.62%
Trees	93.00%	90.29%	Trees	94.68%	93.69%
Urban Land	92.19%	93.65%	Urban Land	94.19%	91.11%
Water	100.00%	77.78%	Water	81.25%	86.66%
Overall Classification Accuracy	90.23%		Overall Classification Accuracy	91.80%	

Table 3. Land-cover within the total selected study area for pre- and post-streamside ordinance categories and selected years that correspond to SPOT image availability.

Generalized Land-Cover Class [1]	1992 (0% of Area within Streamside Ordinance Protection)		2003 (1.64% of Area within Streamside Ordinance Protection)		2009 (43% of Area within Streamside Ordinance Protection)		2012 (43% of Area within Streamside Ordinance Protection)	
	Area (km^2)	**Percent Cover**	**Area (km^2)**	**Percent Cover**	**Area (km^2)**	**Percent Cover**	**Area (km^2)**	**Percent Cover**
Barren Land	0.90	2.72%	0.72	2.18%	0.05	0.16%	0.53	1.59%
Developed Land	5.71	17.22%	8.83	26.65%	11.11	33.52%	13.28	40.08%
Grasses	12.42	37.48%	9.94	30.00%	9.47	28.58%	9.22	27.82%
Trees	12.81	38.65%	12.01	36.23%	10.64	32.10%	8.66	26.14%
Water	1.30	3.94%	1.64	4.94%	1.87	5.64%	1.45	4.38%
Total	33.14	100.00%	33.14	100.00%	33.14	100.00%	33.14	100.00%

[1] User-defined land-use/land-cover classes developed from SPOT imagery.

3.2. Riparian Vegetation Change by Municipality and Ordinance Protection

3.2.1. City of Kansas City

There were declines in the trees and the grasses cover classes and increases in developed land in the Kansas City portion of the study area throughout the analysis period regardless of ordinance protection category. The rate of loss in the trees class following ordinance protection was similar to that of the pre-ordinance periods at about −0.56%/year but was substantially less than the loss

(−2.67%/year) in the non-ordinance area in the 2009–2012 post-ordinance period (Figure 2). Although declines in the grasses cover class continued throughout the analysis period, there was a 0.1–0.2%/year decline in the rate of loss in the post-ordinance period. The rate of loss of the grasses cover in the post-ordinance period (−0.58%/year) also was less than that of the non-ordinance area (−0.86%/year). The rate of change in the developed cover class increased between pre- and post-ordinance periods from about 0.9%/year in the 1992–2002 period to 1.85%/year in the 2009–2012 post-ordinance period. The greatest annualized rate of change in trees (−2.67%, 2009–2012), grasses (−1.22%, 1992–2003), and developed land (3.3%, 2009–2012) were all in the non-ordinance protected area (Figure 2). The area in the northern portion of the Blue River Basin that is outside of the Kansas City ordinance protection buffer zones provides an example of this pattern for the 2009–2012 period, as land cover changed from trees and grasses to developed land (Figure 3).

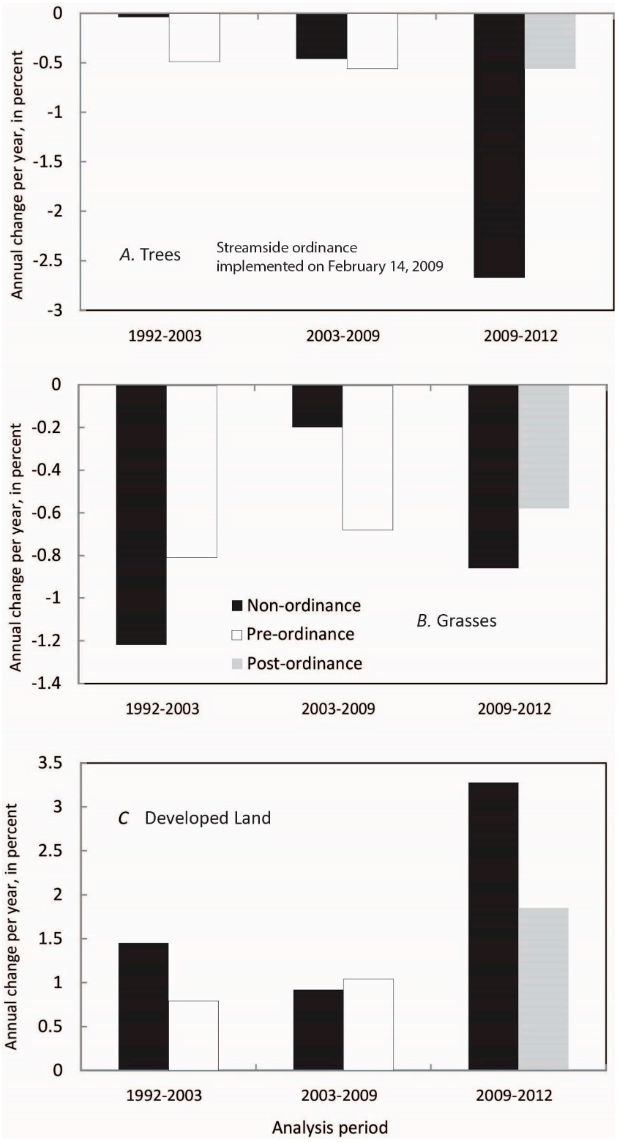

Figure 2. (**A**) Change in Trees within the city of Kansas City, MO, USA, inside and outside the streamside ordinance area during pre-ordinance (1992–2009) and post-ordinance (2009–2012) periods, (**B**) Change in Grasses within the city of Kansas City, MO, USA, inside and outside the streamside ordinance area during pre-ordinance (1992–2009) and post-ordinance (2009–2012) periods, (**C**) Change in Developed Land within the city of Kansas City, MO, USA, inside and outside the streamside ordinance area during pre-ordinance (1992–2009) and post-ordinance (2009–2012) periods.

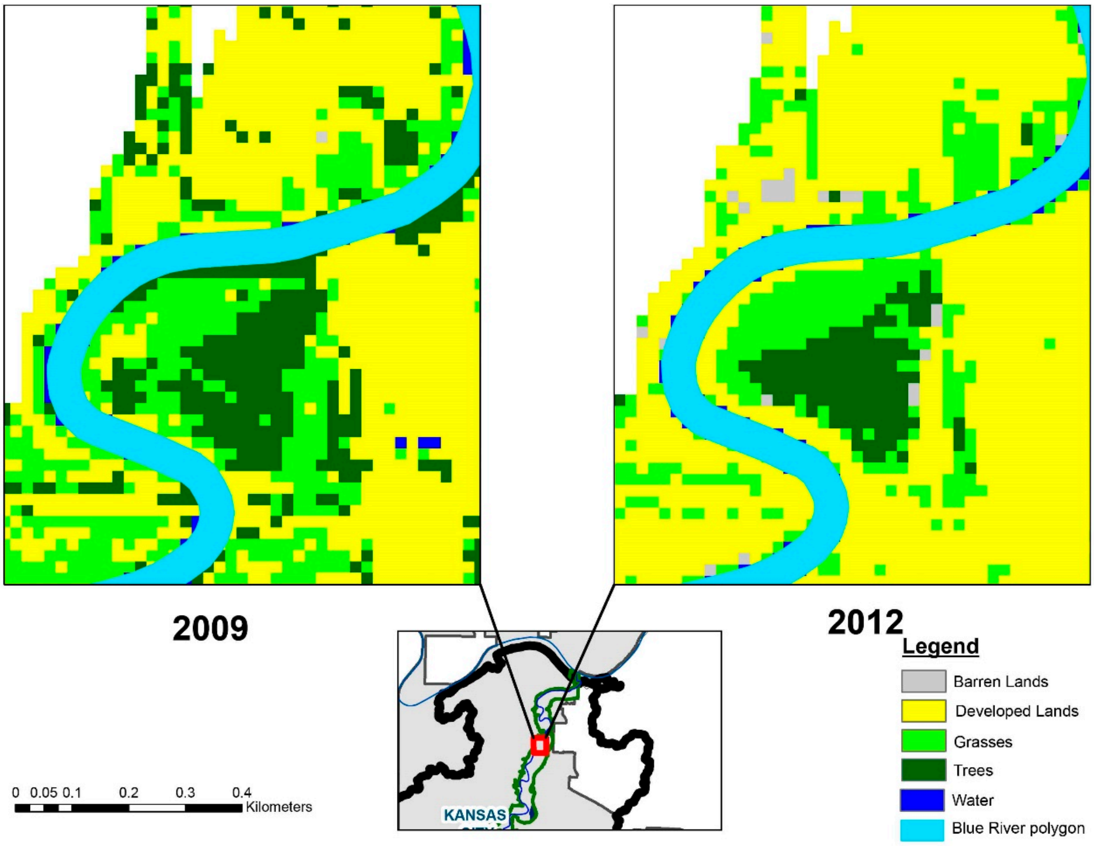

Figure 3. Land-cover classification 2009 and 2012 Kansas City, MO, USA.

3.2.2. City of Overland Park

There were substantial temporal changes in the land-cover classes within the city of Overland Park with changes similar within post-ordinance and non-ordinance areas. Tree loss was greater in the post ordinance period (2003–2012) compared to pre-ordinance period for both ordinance protected and non-ordinance areas (Figure 4). There generally was an increase in the grasses land-cover and developed land in the post-ordinance period for both ordinance protected and non-ordinance areas. The rate of increase in developed land area was greater during the post-ordinance period (2003–2012) in the ordinance-protected area (0.8–2.1%/year) compared to that of the non-ordinance area (0.7–1.4%/year) (Figure 4). The Overland Park ordinance area experienced the greatest loss in trees land-cover from 2003–2009, at 2.06% per year, while the non-ordinance protected area experienced the greatest rate of loss of 3.2% per year from 2009–2012.

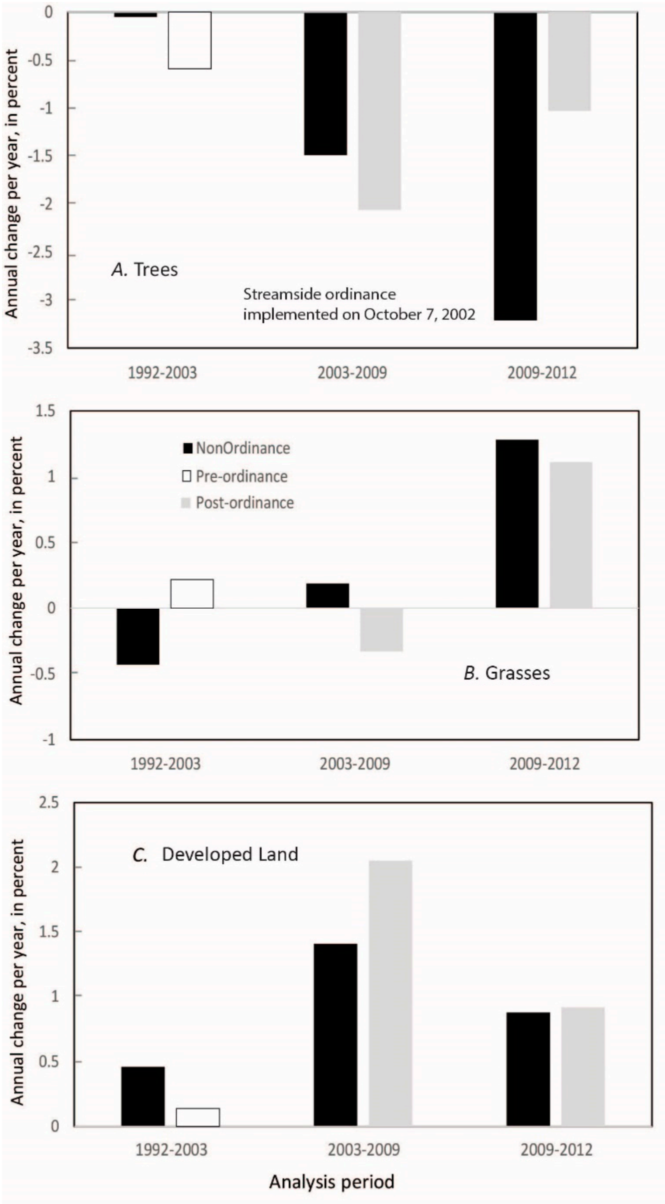

Figure 4. (**A**) Change in Trees within the city of Overland Park, KS, USA, inside and outside of streamside ordinance area during pre- (1992–2003) and post-ordinance (2003–2012) periods; (**B**) Change in Grasses within the city of Overland Park, KS, USA, inside and outside of streamside ordinance area during pre- (1992–2003) and post-ordinance (2003–2012) periods; (**C**) Change in Developed Land within the city of Overland Park, KS, USA, inside and outside of streamside ordinance area during pre- (1992–2003) and post-ordinance (2003 and 2012) period.

3.2.3. Unincorporated Johnson County, KS, USA

The unincorporated Johnson County portion of the study area, an area without ordinance protection, showed the greatest changes in land-cover during the analysis period (Figure 5). There was a consistent loss of trees during each discrete period with the greatest rate of tree loss (−4%/year) occurring in the 2009–2012 period. The grasses land-cover increased from 2003–2012 by a maximum of 3%/year in 2009–2012. The developed land-cover increased during each analysis period, with the greatest increase (1.71%/year) occurring during 2003–2009 and the least (0.2%/year) during the 2009–2012 period (Figure 5).

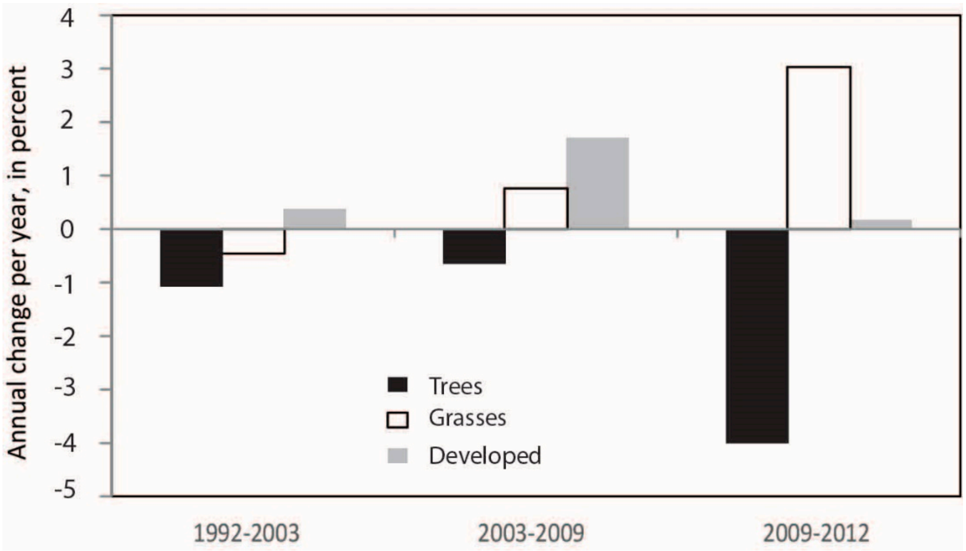

Figure 5. Change in selected land-cover categories within unincorporated Johnson County, KS, USA, during 1992–2012.

4. Discussion

4.1. Total Riparian Vegetation Change within the Study Area

The results indicate that in certain extents of the study area, tree loss increased following the implementation of ordinances, yet areas without any ordinances experienced the greatest losses. This finding is similar to the results of Ozawa and Yeakley [23] and Yeakley et al. [24], which indicated the continued stream buffer loss in selected urban areas in the Portland, OR, USA, metropolitan area resulting from development regardless of the level of regulatory protection.

The temporal trends in the trees and developed land-cover classes in this study are similar to those determined in riparian areas on a national scale by Jones et al. [39], which indicated a loss in riparian forest cover and an increase in the human-use land-cover between the early 1990s and the early 2000s. The magnitudes of change nationally varied with approximately 0.3% increase in human-use and a 0.2% decrease in riparian forest cover between the 1990s and the 2000s. This study estimated a 2.4% increase in developed lands and a 9.4% decrease in trees between 1992 and 2003 for the study extents. Annualized rates of tree loss in this study were greater than the loss rates determined in the Ozawa and Yeakley [23], Yeakley et al. [24] and Jones et al. [39] studies, although this study was much more limited in geographic area.

The streamside ordinances implemented in the study area included exemptions to allow for alterations to the land-cover, in the case of flood abatement projects, through city council approval (88-415-08-B), or mitigation offsets (88-415-07-C) by landowners. This is one possible explanation for the continued loss in riparian vegetation following the implementation of streamside ordinances. Urbanization and the loss of riparian vegetation is associated with an increase in impervious cover, which is one of the primary factors in urban areas for increases in the magnitude and frequency of flooding [40–43]. Stage records from the USGS stream gage at the Blue River near Stanley, KS, USA [44], in the upstream part of the Blue River Basin, indicated that the National Weather Service flood stage [45] was exceeded in 1993, 1995, 2004, 2005, 2008, and 2010. Frequent flooding is an impetus for flood abatement activities that may include the direct removal of high-roughness riparian tree cover or indirect activities that can result in vegetation change including channel alterations (construction of levees and stream channelization).

4.2. Riparian Vegetation Change by Municipality and Ordinance Protection

In addition to differences in ordinance protection by municipality, there are several additional upstream-downstream gradients within the study area that affect the extent of implemented ordinances and the distribution and rate of change in riparian vegetation, including drainage area, history of city establishment, and local economic factors. The ecologically defined extent of the riparian zone, as determined by the aquatic-terrestrial transition, will increase proportionally to the drainage area and may exceed the width of ordinance protection. The ordinance-protected streamside width can be absolute or be proportional to drainage area up to an arbitrarily defined maximum. The city of Kansas City was established many decades prior to Overland Park, and ordinance protection within the city of Kansas City portion of the study area was established well after development and growth along the Blue River floodplain. In Overland Park, development is continuing within the basin during the post-ordinance period. The unincorporated Johnson County, KS, USA, reach along the Blue River largely is rural and semi-suburban and development is still in its early stages. This disparity in the timing and extent of development results in substantial differences in land values along the Blue River corridor, which in turn, can affect the cost of vegetation protection.

The city of Kansas City provides the greatest lateral width of streamside vegetation protection in the study area, but it still provided a non-continuous and patchwork application of the ordinance. The results indicated that a lower rate of land-cover change, including vegetation loss, occurred in the ordinance-protected area compared to the non-ordinance area. However, the greatest rate of tree loss and increase in developed land occurred following the implementation of the streamside ordinance in 2009–2012. Building permits issued in Kansas City prior to the streamside ordinance are not subject to ordinance restrictions. This could explain some of the increases in tree loss and the developed land class since there could be a pressure to complete the development before the granted permissions expire. This exemption would be expected to decrease with time as the previously granted permits were completed and all future works were controlled by the streamside ordinance. Another consideration in explaining the rate and timing of vegetation changes within the Kansas City ordinance zones is the Blue River Channel Modification Project [46]. The project was authorized by the US Congress in 1970, cost over $300 million in Federal funds, and with the goal of reducing the risk of flooding in the lower Blue River in Kansas City. Implementation extended from 1983 through 2016 and included three stages of construction covering 20.1 km of Blue River channel. Modifications to the channel included channelization, streambank armoring, and alterations to vegetation within the near-channel riparian areas. Flooding in 2010 along the lower Blue River led to increased efforts in the flood abatement project including bank stabilization that could account for a part of the increased rate of vegetation loss and increased rate of development between 2009 and 2012.

Unlike the city of Kansas City, which has an absolute buffer width, the city of Overland Park implemented an ordinance zone that was proportional to the drainage area of the stream. The maximum width, however, remained constant in streams with drainages over 20 km^2 leaving a substantial part of the study area extent outside of the ordinance area within the Overland Park reach. Real estate values also may be a factor in determining the extent of riparian protection along the Blue River riparian area. For instance, the median house value in Overland Park was over $100,000 greater than the median house value in Kansas City [47]. This disparity in the value of protected lands also could account for differences in the extent of ordinance protection.

The unincorporated Johnson County, KS, USA, does not have a streamside ordinance to prevent the alteration or removal of vegetation within the riparian corridor. Such a lack of protection facilitates the temporal and downstream-to-upstream spatial progression of riparian vegetation alterations that have occurred in the basin. The greatest rate of tree loss occurred in this rural segment of the study area, but the losses did not correspond to increases in developed land but rather to an increase in the grasses cover. This area was the only area within the study area that had a net increase in grasses cover. It is possible that the increase in the grasses land-cover may have been a result of the clearing of the treed lands for recreational or flood reduction purposes, which moved the land-cover into the grasses class.

The results demonstrated that a water body and associated riparian area such as the Blue River that spans many jurisdictional boundaries can have varying levels of protection resulting from inconsistencies in the content and implementation of streamside ordinances. In such instances, established ordinances can potentially limit further degradation of impaired water bodies but, afford little remediation to existing impairments or offer insubstantial effects on upstream sources of impairment [48]. The ordinance provisions should address the primary focal issues of the jurisdictional area whether it be erosion control, vegetation loss, or flood purposes. The implementation of streamside ordinances alone will not provide protection of riparian vegetation without consistent and unified effective oversight [17]. To be most effective, the ordinances need to be implemented with adequate spatial coverage, to contain provisions that address protection needs, and to be enforced to ensure that the policies are actually being used for intended governance.

5. Conclusions

The rates of the land-cover changes were not consistent either temporally or spatially within the study area. The streamside ordinances did not result in a reduction in the rate of land-cover change and losses within the tree land-cover class and increases in developed lands continued following the implementation of ordinances within protected areas. In fact, the rate of tree loss and gains in developed land classes increased following the implementation of ordinances, albeit at a lower rate compared to areas without ordinance protection.

The missing or weak cooperation among adjacent municipalities and jurisdictions at a watershed level poses a risk to the maintenance and function of riparian vegetation in the Blue River Basin despite 43% of the area being under ordinance protection. As each jurisdiction allocates for its own impacts, careful consideration should factor into what is happening upstream and downstream to ensure that their management plans are appropriate and adaptable. There are documented upstream-downstream gradients in water quality, stream physical habitat, and in biological metrics along the Blue River main stem [49]. The decrease in these factors from upstream to downstream sampling locations were related to an increase in impervious area, streamflow contributions from waste water treatment plants, and channel alterations, and loss of riparian vegetation. The implementation of consistent ordinances along the entire longitudinal extent of a stream affords an effective means of protection or management of such gradients. In contrast, a patchwork and inconsistent implementation of streamside ordinances substantially reduces the effectiveness of protection efforts.

An assessment of the effectiveness of streamside ordinances should be a part of a river protection management plan. To ensure the success of such assessment, the approaches need to be designed and developed with proper spatial and temporal considerations, as relevant to the study objectives. Geospatial techniques including remote sensing and GIS analysis prove to be useful in assessing urban environmental issues both spatially and temporally [50,51]. The assessment results provide supporting data for local decision makers to make policy changes to prevent further environmental degradation.

The highest rate of vegetation change within ordinance-protected areas in this study generally occurred following the implementation of streamside ordinances. The study period included an economic recession and correspond decline in commercial and housing development, which could have influenced the results due to economic incentives and the timing of the market correction. Areas without protection experienced the greatest impacts and have the greatest room for improvement from policy changes. Future studies could incorporate economic data at a suitable scale to determine possible drivers of the timing and extent of riparian vegetation loss.

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