"Measuring the pulse" of urban green infrastructure: vegetation dynamics across residential landscapes

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INTRODUCTION

Urban vegetation cover has been largely investigated in relation to urban morphology (Luck et al. 2009, Lowry et al. 2012, Bigsby et al. 2014) and socio-economic settings of neighborhoods (Grove et al. 2006, Grove et al. 2014, Schwarz et al. 2015).

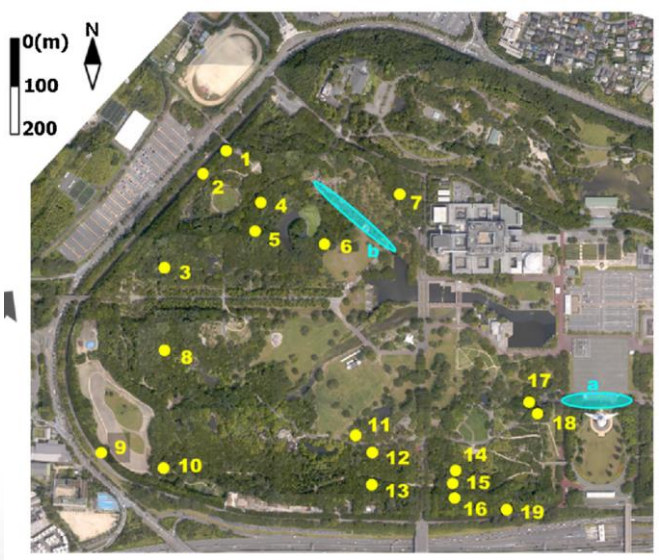
Urban vegetation structure, rather than its cover *per se*, affects biophysical and micro-climatic characteristics of urban green spaces (McPherson et al. 1997, Davis et al. 2016, Hall et al. 2016), ecological and hydrological processes (Ossola et al. 2015a, Ossola et al. 2016), as well as the provision of habitat for biodiversity (Stagoll et al. 2012, Le Roux et al. 2014, Ossola et al. 2015b).

Various studies assessed canopy cover temporal dynamics, but little evidence exists on vegetation structure changes over time, particularly in areas where access for fieldwork is limited or restricted.

LiDAR used to assess tree growth (Næsset and Gobakken 2005, Hopkinson et al. 2008) and changes in tree biomass (Meyer et al. 2013, Økseter et al. 2015, Cao et al. 2016) in rural forests and plantations.

Naturally-occurring canopy gap opening and closure, as well as fallen and harvested trees dynamics have also been monitored (Yu et al. 2004, Vepakomma et al. 2008, Vepakomma et al. 2010, Vepakomma et al. 2011).

Urban vegetation structure dynamics over a 6-year period in a single urban park in Osaka, Japan (Song et al. 2016).



RESEARCH QUESTIONS

1 - Can medium-resolution LiDAR datasets collected at a 5-year interval be used to measure urban tree loss dynamics across residential landscapes in different cities?

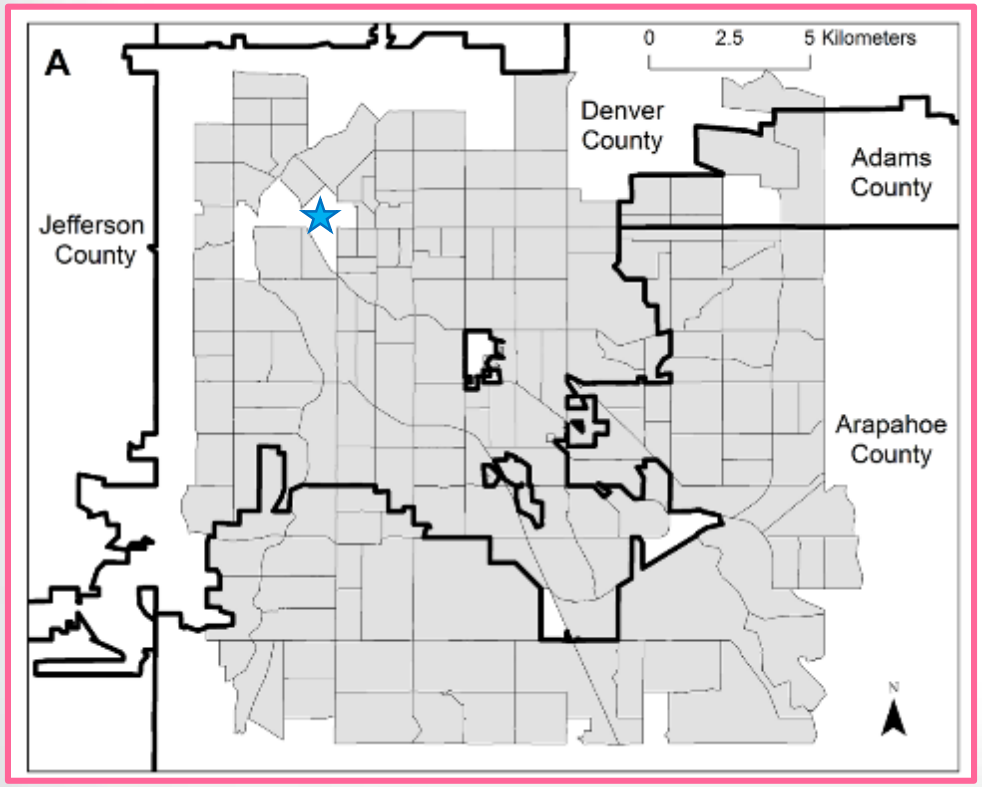
2 - Are residential tree loss dynamics (i.e. number of stems lost in a 5-year period and their height) related to the morphological and socio-economic characteristics of residential neighborhoods?

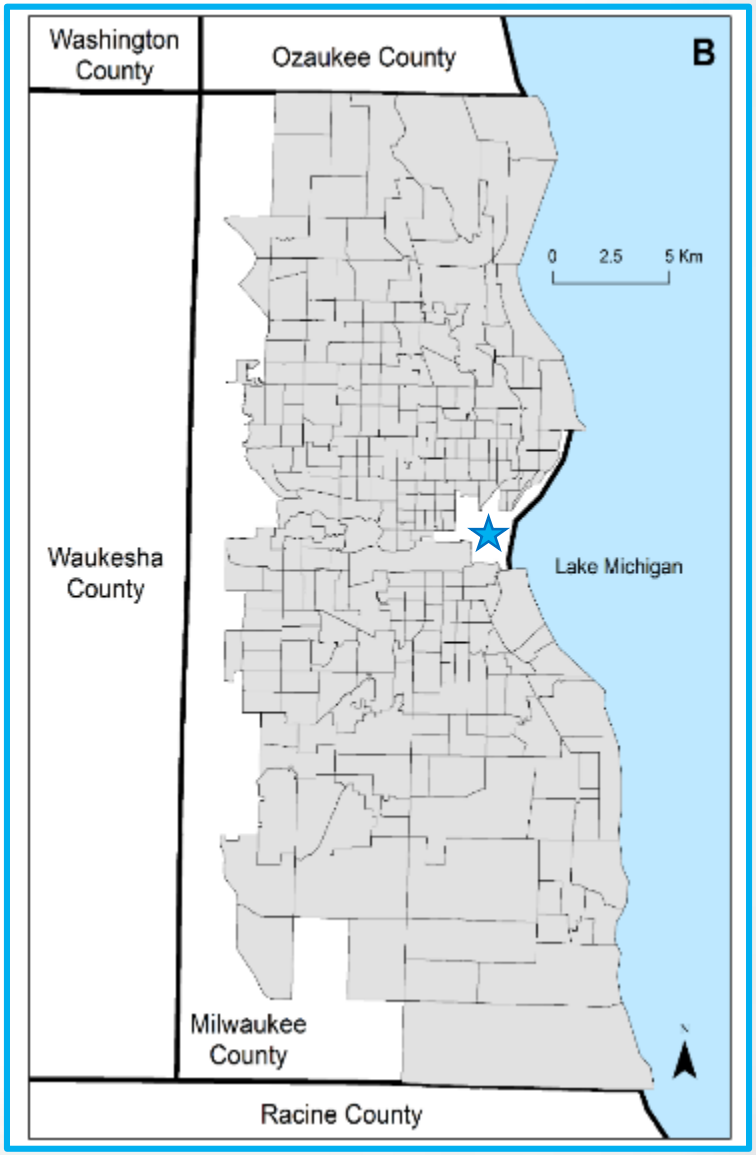
METHODS

downtown
census tract

A) Denver, CO – 448 km^2, 177 census tracts, 187,478 residential parcels.

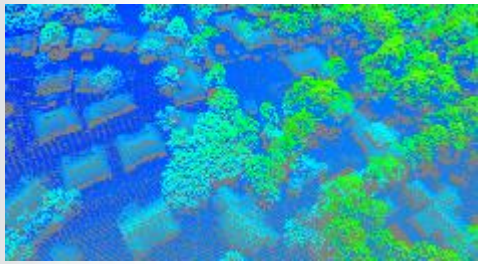
B) Milwaukee, WI – 516 km^2, 267 tracts, 213,227 residential parcels.





METHODS

Airborne LiDAR point clouds collected at a 5 year interval



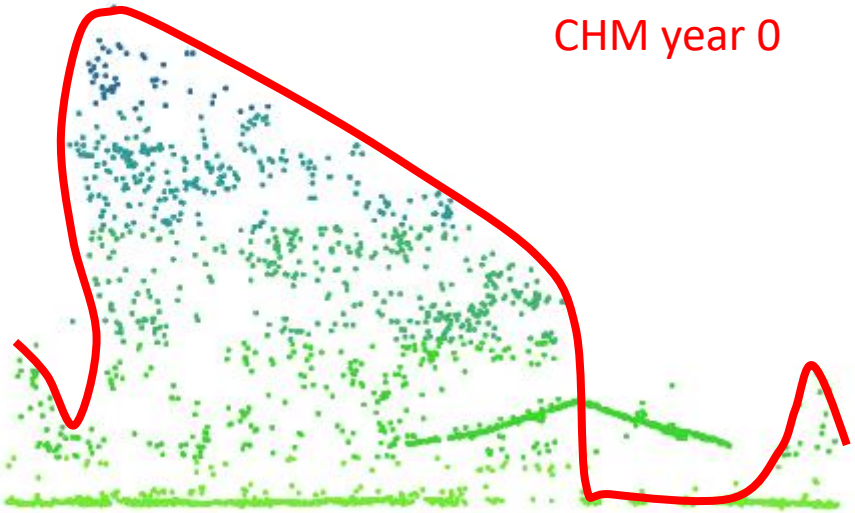
Dataset name	USGS LPC CO Denver 2008	USGS LPC CO South Platte River Lot 5 – 2013	2010 Milwaukee County LiDAR	2015 Southeast WI Counties LiDAR
Study area	Denver, CO	Denver, CO	Milwaukee, WI	Milwaukee, WI
Collection period	25.03.2008 19.04.2008	25.10.2013 31.05.2014	16.04.2010 18.04.2010	24.03.2015 03.04.2015
Nominal point spacing (m)	0.7	0.7	0.7 *	0.7 *
Min. point spacing	0.444	0.391	0.433 *	0.364 *
Mean point spacing	0.603	0.439	0.542 *	0.457 *
Max. point spacing	0.76	0.627	0.779 *	0.854 *
Tile size (km)	1.5 x 1.5	1.5 x 1.5	1.5 x 1.5	3 x 3
N. tiles	196	196	291	88

* The original unit of measure of the 2010 Milwaukee County LiDAR ad the 2015 Southeast WI Counties LiDAR datasets is the US foot which has been converted to meter using the equivalency 1 foot = 0.3048 m.

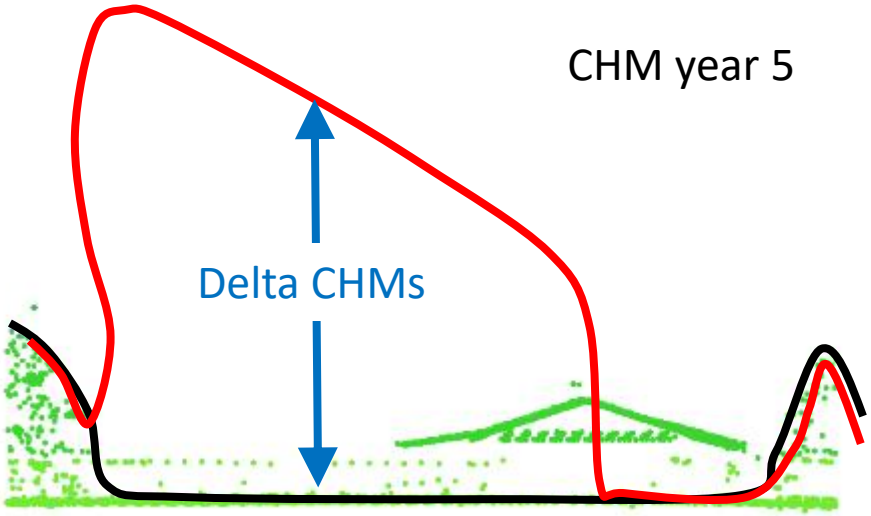
Multispectral imagery (RBG, NIR) at 1 m resolution (USDA-NAIP).

METHODS

YEAR 0
Google earth

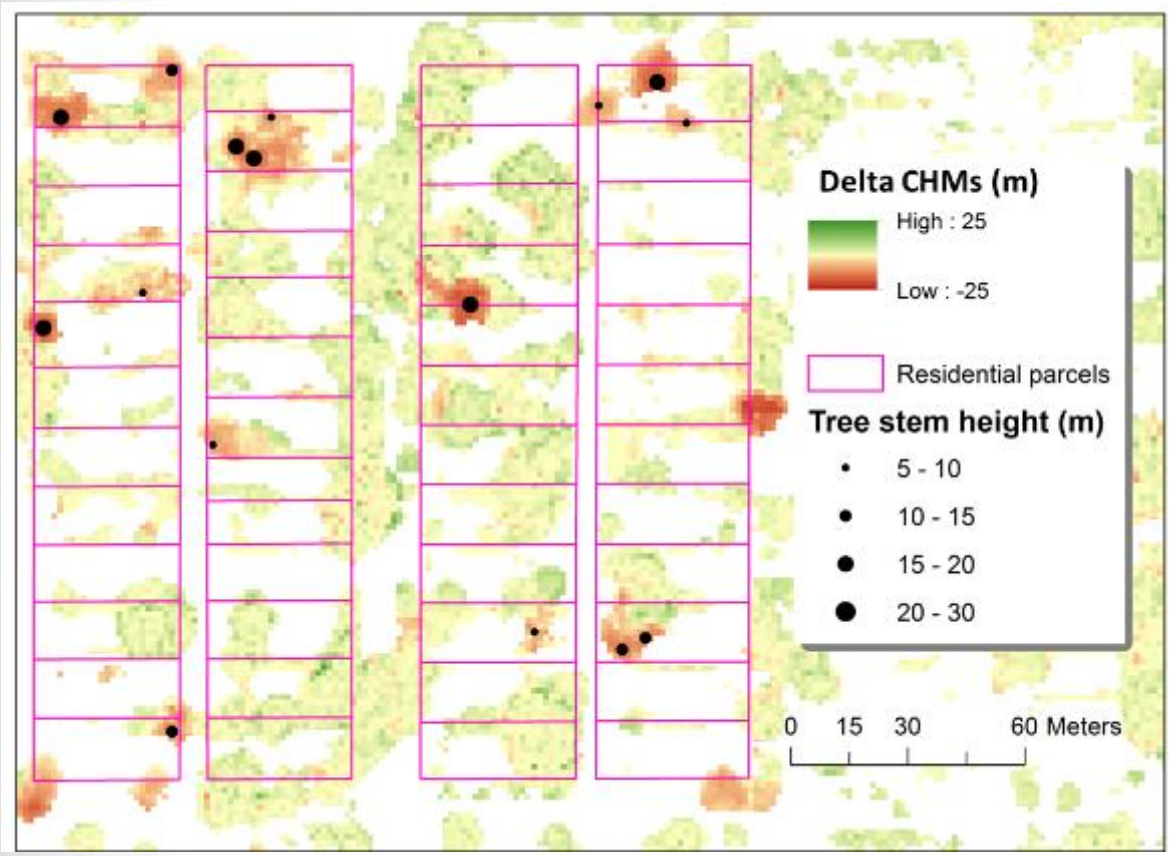

CHM year 0

YEAR 5
Google earth


CHM year 5
Delta CHMs

METHODS

Tree stem (•) extraction from –ΔCHMs using *rLiDAR*



Fitted multivariate regression linear models to predict: i) n. stems lost per tract and ii) average tree stem height based on A) *urban morphological* variables, B) *socio-economic variables*, and C) both urban morphological and socio-economic variables (*global*, A+B).

A	**Model type: *Urban morphology***	
	Denver, CO	**Milwaukee, WI**
	Canopy cover (initial year)	Canopy cover (initial year)
	Decade max housing development	Decade max housing development
	Average parcel area	-
	Housing density	Housing density
	Percent residential land use	Percent residential land use

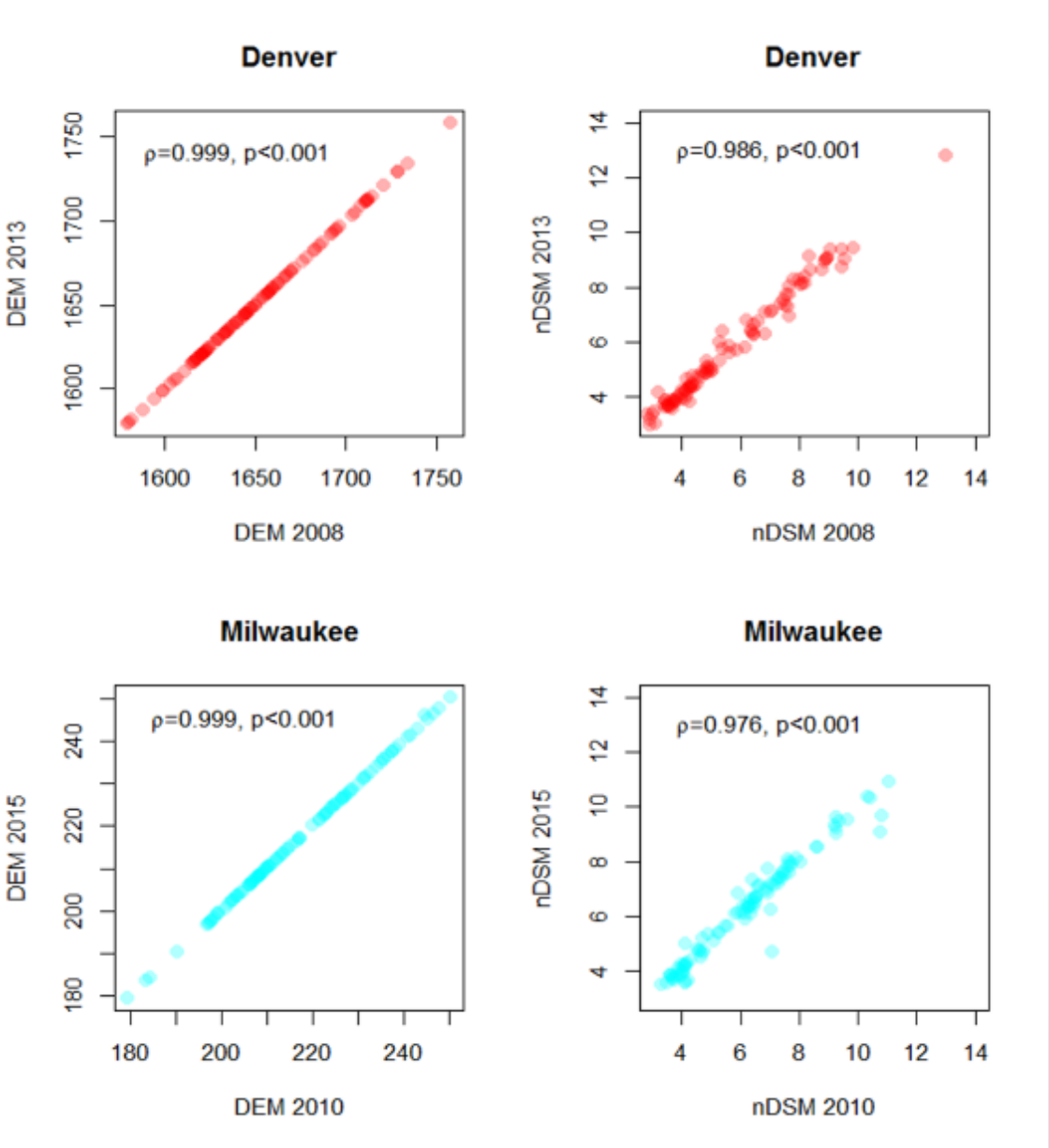
Models selection using AICc.

RESULTS

Calibration LiDAR temporal datasets using DEMs and nDSM

Accuracy and reliability of vegetation classification >91%

Accuracy tree stem extraction with *rLiDAR* >95%

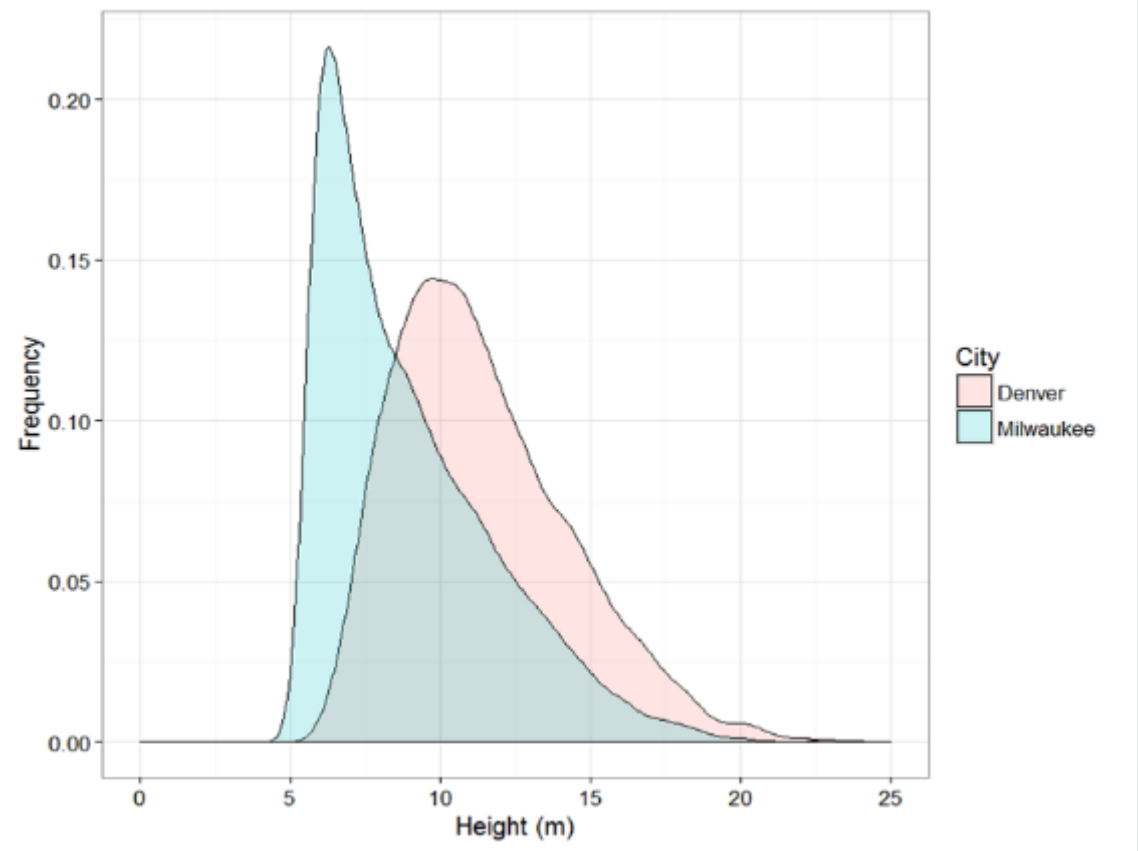


RESULTS

13,427 and 15,000 tree stems (height > 5m) lost in Denver (2008-2013) and Milwaukee (2010-2015)

99.33 ± 3.49 (Denver) and 82.41 ± 2.14 (Milwaukee) tree stems lost per km^2 of residential area

Tallest stems lost in Denver and Milwaukee were 28.04 and 23.82m high



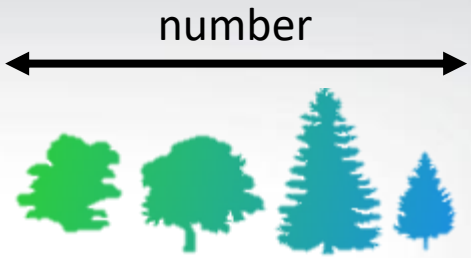
RESULTS

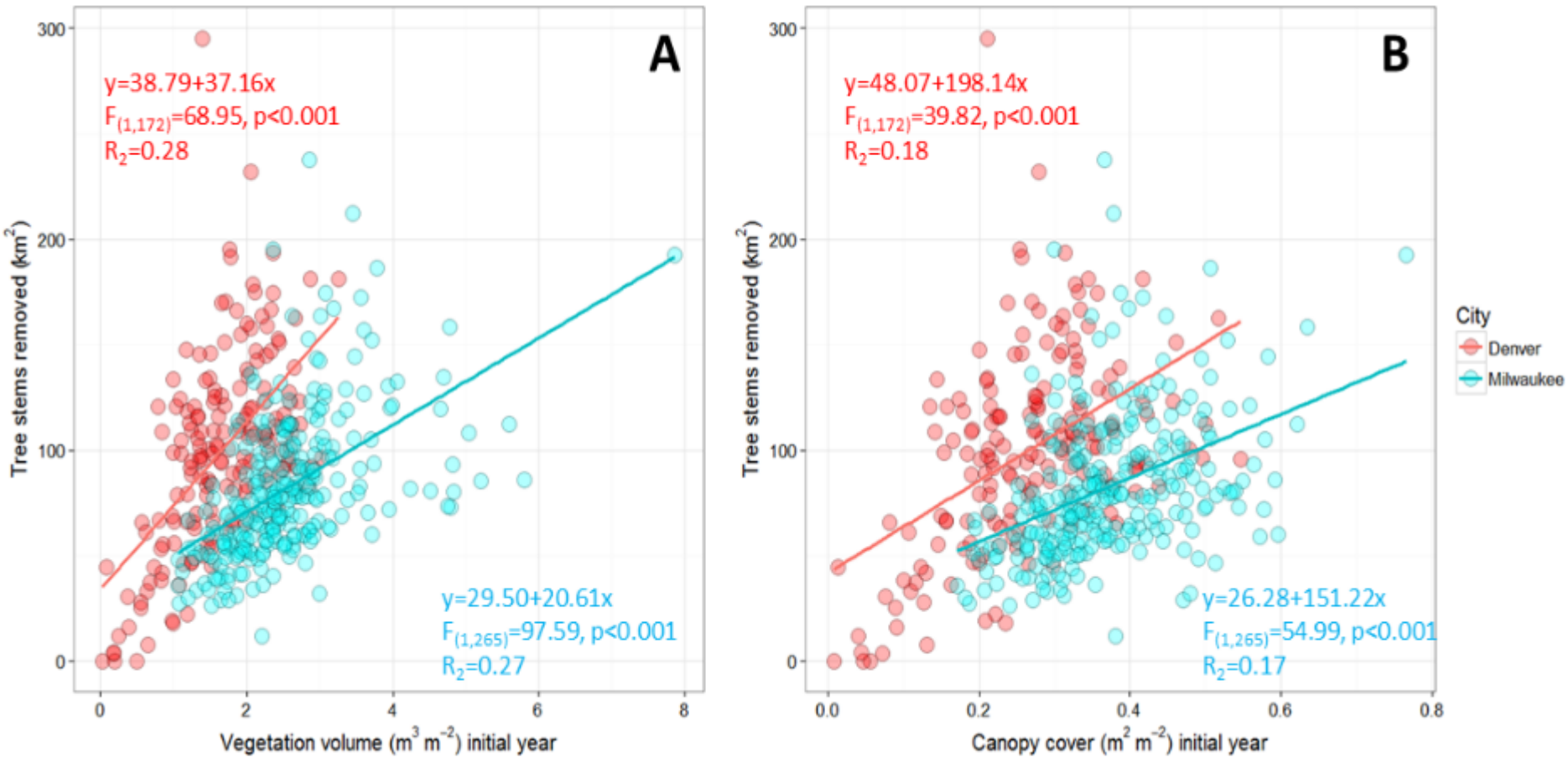
RESULTS

number

Response variable: n. tree stems lost (km^2)	**Denver**			**Milwaukee**		
Model type	Urban morphology			Global		
Predictor variables	**Estimate**	**Std. error**	**p**	**Estimate**	**Std. error**	**p**
Canopy cover (initial year)	*9.87*	*1.67*	***< 0.001***	*2.63*	*0.37*	***< 0.001***
Decade of max housing development	*-0.06*	*0.01*	***< 0.001***	-0.001	0.002	0.55
Average parcel area	-0.49	0.33	0.14	-	-	-
Housing density	-0.04	0.23	0.87	-0.03	0.08	0.73
Percent residential land use	0.01	0.01	0.13	-0.001	0.001	0.83
Median age	-	-	-	-0.32	5.61	0.11
Racial diversity index	-	-	-	*-0.38*	*0.15*	***< 0.05***
Family/non-family ratio	-	-	-	0.10	0.10	0.34
Percent vacant units	-	-	-	0.01	0.06	0.87
Gini index	-	-	-	0.74	0.91	0.22
Percent unemployed	-	-	-	-0.04	0.04	0.25
Monthly rent	-	-	-	0.01	0.15	0.94
Degrees of freedom	166			249		
R^2 / Adj R^2	0.48 / 0.46			0.29 / 0.28		
F-statistic (p-value)	30.2 (< 0.001)			26.27 (<0.001)		

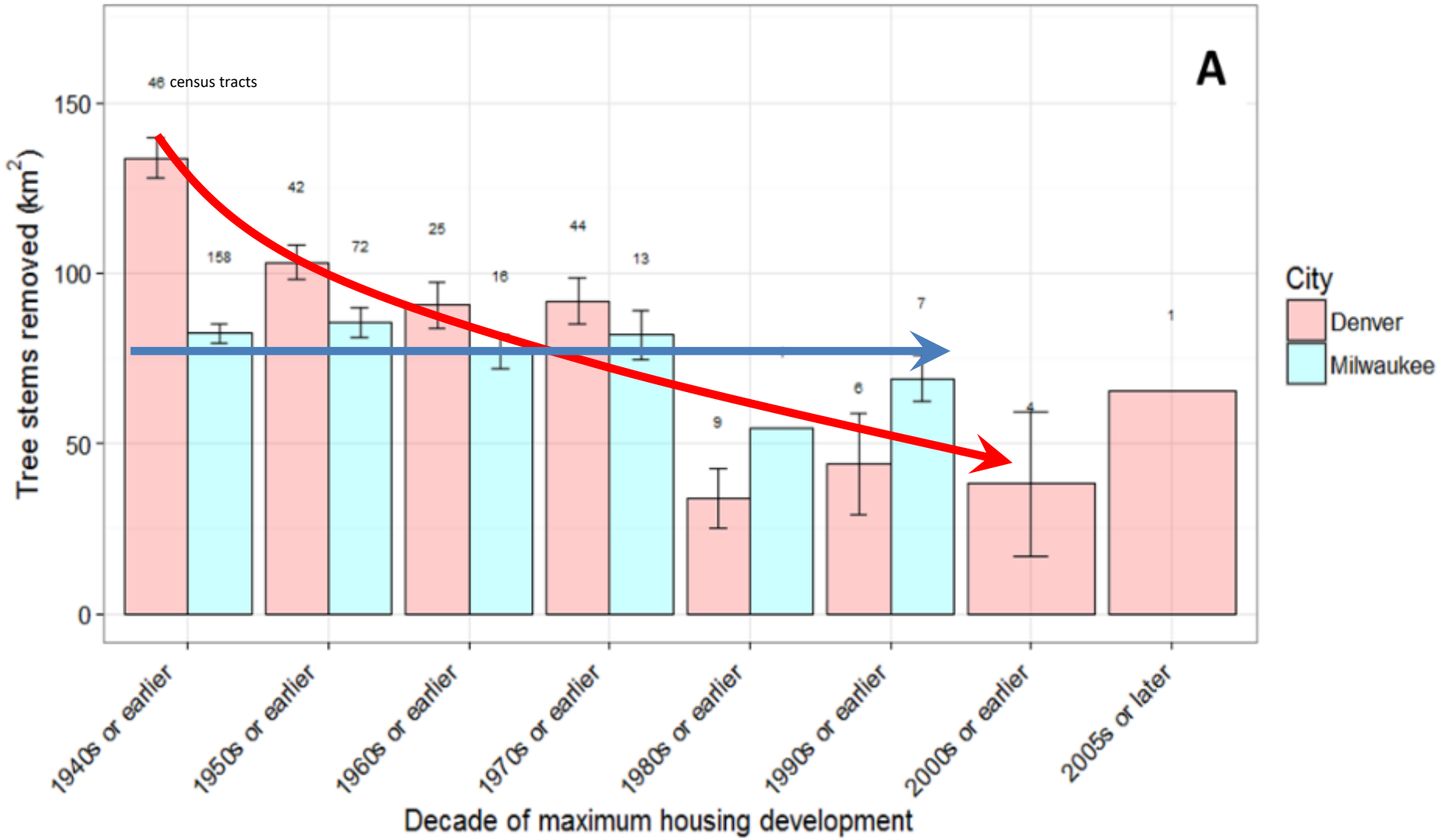
RESULTS


number


A
y=38.79+37.16x
F(1,172)=68.95, p<0.001
R2=0.28
y=29.50+20.61x
F(1,265)=97.59, p<0.001
R2=0.27
Tree stems removed (km2)
Vegetation volume (m3 m-2) initial year
B
y=48.07+198.14x
F(1,172)=39.82, p<0.001
R2=0.18
y=26.28+151.22x
F(1,265)=54.99, p<0.001
R2=0.17
Canopy cover (m2 m-2) initial year
City
Denver
Milwaukee

RESULTS

number



RESULTS

height

Response variable: tree stem height (m)	**Denver**			**Milwaukee**		
Model type	Global			Global		
Predictor variables	**Estimate**	**Std. error**	**p**	**Estimate**	**Std. error**	**p**
Canopy cover (initial year)	0.72	0.82	0.38	0.42	0.67	0.54
Decade of max housing development	-0.001	0.001	0.65	-0.01	0.01	0.13
Average parcel area	0.14	0.15	0.38	-	-	-
Housing density	0.15	0.14	0.30	0.02	0.14	0.91
Percent residential land use	0.001	0.001	0.17	0.01	0.01	0.19
Median age	0.17	0.44	0.70	0.07	0.37	0.84
Racial diversity index	-	-	-	-0.09	0.27	0.72
Percent families below poverty	*-0.17*	*0.05*	***< 0.001***	-	-	-
Family/non-family ratio	0.03	0.23	0.91	0.14	0.18	0.43
Percent vacant units	*-0.33*	*0.16*	***< 0.05***	-0.23	0.12	0.053
Gini index	*2.90*	*0.89*	***< 0.01***	-1.89	1.11	0.08
Percent unemployed	0.05	0.08	0.53	-0.05	0.07	0.48
Monthly rent	-0.21	0.26	0.40	0.22	0.26	0.40
Degrees of freedom	156			249		
R^2 / Adj R^2	0.38 / 0.33			0.16 / 0.13		
F-statistic (p-value)	7.93 (< 0.001)			4.44 (< 0.001)		

DISCUSSION

- Medium-resolution LiDAR datasets can be used to monitor tree loss dynamics across entire urban landscapes.

- Higher-resolution LiDAR data could be used to assess vegetation growth and species-specific dynamics.

- Tree loss appears to be a widespread phenomenon across urban residential landscapes.

- Further evidence is needed to understand people's values and preferences towards large old trees and the motivations leading to urban tree removal and loss.

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