Prairie Perspectives: Geographical Essays

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PRAIRIE PERSPECTIVES: GEOGRAPHICAL ESSAYS

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Preface

Prairie Perspectives: Geographical Essays is published in coordination with the annual meeting and conference of the Prairie Division of the Canadian Association of Geographers (PCAG). The 2016 annual meeting ran from September 23 to 25 and was held in Melfort, Saskatchewan, where it was hosted by the University of Saskatchewan. A total of 72 attendees gathered for the conference, which consisted of paper presentations, a poster session, a field trip, executive and business meetings, and a banquet. The decision to assemble in Melfort holds to the long-held PCAG tradition of hosting the annual meeting event at a location outside the main urban centres of the prairie region. Melfort is located 150 km northeast of Saskatoon and is home to a population of 6000 (2016). Typical of most small Saskatchewan prairie cities, it has a rich farming history and provides a wide range of central place functions to its agricultural hinterland.

Conference activities were staged in the fabulous Kerry Vickar Centre, a facility named after a highly successful businessman and philanthropist who was born and spent his childhood in Melfort. On Saturday morning a total of 18 papers were presented in a series of four sessions. Eight of these papers were presented by students each of whom was awarded a Paul Simpson-Housley/CAG Student Travel Award and a one-year annual membership of CAG. In the early-morning, two concurrent sessions commenced. The first was a session on Remote Sensing chaired by Dr. Xulin Guo, University of Saskatchewan, while a second session on Environment, Planning and Governance was chaired by Dr. Joseph Piwowar, University of Regina. Following these concurrent sessions there was time for coffee and poster viewing. A total of fourteen posters were presented, seven of these were presented by students each of whom was awarded a Paul Simpson-Housley/CAG Student Travel Award and a one-year annual membership of CAG. Following the poster presentations, and in mid-morning, two concurrent paper sessions commenced. The first session was on Resources and Geomorphology chaired by Dr Dirk de Boer, University of Saskatchewan, while a second session on Human and Historical Geography was chaired by Dr Ryan Walker, University of Saskatchewan.

On Saturday afternoon most attendees participated in a field trip to learn more about the cultural history of Melfort and its immediate hinterland. The trip consisted of three tours. These were organized by staff and volunteers of the Melfort and District Museum and, in particular, by Gailmarie Anderson. The first tour, taken by bus, visited historic churches of the region and the community of Edenbridge. Verna Tluchuk guided this tour with Melfort city councillor Bob Jung also attending. Extensive notes describing the tour are provided by Jock Lehr in this volume. The second tour comprised a walking excursion through Melfort's historic downtown. This included viewing of a video titled Virtual Melfort at the Melfort Public Library, and a visit to the city's Historic Post Office (c 1912). The latter including a climb up the building's clock tower. Museum volunteers Alan Porter Coffee and Michelle Waldbillig served as tour guides. The final tour was of the Melfort Museum and was led by Dale Link, Larry Sparks, and Gailmarie Anderson. The group toured the 18 buildings on display at Pioneer Village including a grist mill, blacksmith shop, sawmill, and general store. PCAG is grateful to Gailmarie and the other volunteers for their superb efforts in coordinating the afternoon field tours. Many thanks to all for a great job!

The evening banquet was held at the Kerry Vickar Centre. The PCAG guest speaker was CAG National President Dr. Dan Shrubsole, who spoke on the topic of "Leadership and Taking Care of Yourself: Personal Reflections on Integrated Water Management Research and on Mentoring." The talk was very well received. The evening concluded with remarks from PCAG President Dr. Derrek Eberts, the annual slide show competition, and an awards ceremony in which Dr. Matt Dyce, University of Winnipeg, received the Early Career Award. This award recognizes new faculty members who have made outstanding contributions to the geography of the western interior. Congratulations Matt.

Prairie Perspectives: Geographical Essays is the annual peer-reviewed journal of the PCAG. The papers within are often based on presentations at the PCAG meeting but are also drawn from a wide community of scholars including association members, geographers working at prairie institutions, and those not based in the region but working on topics relevant to prairie geography. Volume 19 is composed of seven research papers grouped into technical and human aspects of geographic inquiry.

The technical geography papers begin with Jacqueline Binyamin and Robyn Ploquin's exploration of factors that control light use efficiency to improve global estimates of carbon uptake from the terrestrial biosphere using white pine as the study sample. Next, Bradley Doff and Todd Randall report on their use of a GIS-decision support tool called the Urban Forest Benefits Model. They explore the potential of this tool to develop an inventory and framework of urban forest benefits calibrated for a specific city in order to assist with the sequencing of greening activities such as planting, maintenance, and protection, to optimize community co-benefits and attain long-term urban sustainability goals. Mirva Travland, Abdul Raouf, and Tayab Shah explore the feasibility of remote sensing and GIS techniques to demonstrate their potential for identifying and classifying park and conservation area facilities with special emphasis on the classification of a trail system in the Wakamow Valley, Saskatchewan. The authors' goal is to develop an information system for efficient management and improvement of park facilities. Ulrike Hardenbicker and Brent Bitter venture to Saskatchewan's Avonlea Badlands to evaluate the potential of using high digital elevation models to reveal subsurface erosion features and the connectivity of surface and subsurface drainage networks. They conclude that identifying subsurface erosion processes could help in understanding high erosion rates and sediment yield in badland environments.

In the first human geography paper, Lindsay Herman explores 'whiteness studies' to evaluate the colonization and racialization of non-white communities in the Prairie west. Herman notes that while whiteness studies in geography are growing in popularity across North America, the Canadian prairies offer a unique social, spatial, and economic landscape for study, providing conditions where lower concentrations of visible ethnic minority communities lead to the erasure of these group experiences in social and spatial terms. Herman's paper examines the past and present experiences of Chinese-Canadian communities, living with whiteness as a norm in the Canadian prairies. In the next paper, Julia Siemer and Keir Matthews-Hunter examine the spatial dynamics of urban gentrification in Berlin, Germany. Their study focuses on districts of former East Berlin, where gentrification of the inner city began post-1990 reunification of the German state. They also consider former West Berlin, where the process has since diffused. Siemer and Matthews-Hunter's paper concludes with a spatial analysis of potential future development areas in Berlin. Closing the human geography category, Christin Kleinschmidt, Robert Patrick, and Marius Mayer describe a project in Saskatoon, SK, where they conduct a study into participant perceptions of benefits arising from community gardens. They show the benefits of shared work-effort and communal work spaces were strongly represented in the case study results.

This volume of *Prairie Perspectives: Geographical Essays* marks the 40th anniversary of PCAG. The papers presented herein provide a glimpse into the diversity of scholarly work undertaken by geographers in, and of, the prairie region.

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Treaty 6

Acknowledgements

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Prairie Perspectives:
Geographical Essays

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Examination of light use efficiency in three temperate pine plantations in southeastern Canada: Age effect case study

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Photosynthetically active radiation (PAR), gross ecosystem productivity (GEP) and net ecosystem productivity (NEP) are described for white pine plantations during the growing season at three sites of different ages. The fraction of absorbed photosynthetically active radiation (faPAR) was calculated in order to produce values for light use efficiency (LUE) in white pine at all three sites. Age effects were also observed through GEP, NEP, and LUE. Yearly PAR is mostly constant for the duration of the study at all of the sites with one exception at TP02 in 2013. GEP and NEP peak in stands that are of middle age, and decrease in older stands. GEP at TP02 gradually increases over the six years as the stand matures. GEP and NEP often have an opposing relationship, depending on the values of respiration (R) which are affected by temperature, water availability or other factors. The relationship between GEP and NEP varies seasonally and is affected by local weather events, such as drought. During drought, GEP and NEP decrease due to lower respiration. faPAR values increase as the stands aged, increasing from 0.94 at TP02 to 0.97 at TP39. This is due to the incapability of younger trees to absorb as much light as older trees. Seasonal patterns were difficult to deduce at TP02 and TP74 due to missing data. However, at TP39, faPAR clearly peaked during the summer months and decreased in spring and fall months. LUE follows the pattern shown for GEP at all three sites. At TP02, as the stand was maturing, the LUE increased over the six-year study period (2008–2013). LUE also increased at TP74 but decreased at TP39 over the study period. This means that LUE decreases in plantation stands over time. Age also affects the GEP and the NEP, which both generally decrease as the trees age.

Keywords: net ecosystem productivity, gross ecosystem productivity, photosynthetically active radiation, white pine, light use efficiency

Introduction

Light use efficiency (LUE) is the ability of vegetated canopies to use light for photosynthesis. LUE and the effect of age on trees is an important topic in today's world, especially with deforestation as a concern. LUE is the amount of atmospheric carbon uptake by vegetation per unit energy absorption (Asner et al. 2004) and it decreases in relation to several environmental factors including extreme temperatures, water and nutrient shortage, and exposure to high light intensities (Goerner et al. 2011). A better understanding of the factors that control LUE will result in improved global estimates of carbon uptake from the terrestrial biosphere. Studying LUE in white pine is especially important due to its ability to flourish almost immediately after a disturbance (Restrepo and Arain 2005). Because of this ability, white pine is a preferred succession and plantation species in eastern

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North America (Restrepo and Arain 2005). White pine is also an economically valuable species as it grows efficiently on nutrient poor, sandy soils where other deciduous and conifer species cannot survive (Parker et al. 2001).

Flux measurements such as gross ecosystem productivity (GEP), net ecosystem productivity (NEP) and photosynthetically active radiation (PAR) can be measured by the eddy covariance technique and are important in assessing and monitoring the wellbeing of white pine in order to study the longer term growth of the species. GEP is controlled by shortwave radiation emitted by the sun, air temperature, water stress, water vapour deficit, leaf-area index and the distribution of leaves or needles in the canopy (Wen et al. 2010). NEP is the net exchange of carbon between the ecosystem and the atmosphere and it results from the balance between carbon uptake through photosynthesis (GEP) and carbon release through respiration and decomposition (Barr et al. 2002). GEP, NEP and PAR measurements provide information on the overall production of the forest. From these measurements, faPAR and LUE can be derived. The faPAR refers to the fraction of absorbed photosynthetically active radiation (Goerner et al. 2009) and describes the light absorbing properties of the vegetation in a region (Moreno et al. 2012). The faPAR is known to be strongly related to water stress and it has been proposed as a drought indicator (Gobron et al. 2005; 2007).

In this study, the upwelling and downwelling PAR is measured in order to determine faPAR and in combination with GEP these data are used to derive LUE patterns in white pine (*Pinus strobus* L.). LUE is a critically important determinant of NEP in ecosystems (Asner et al. 2004) and it varies in space and time due to environmental stresses limiting the photochemical reaction process (Hilker et al. 2008). Therefore reliable estimation of NEP requires a deep understanding of the environmental effects on LUE and the acquisition of high-quality environmental data. Alton (2008) showed that LUE of carbon uptake increases with the ratio of diffuse to direct shortwave radiation reaching the canopy by a factor of 1.12 to 1.80 and needle leaves orientation within the canopy is the primary cause of LUE enhancement.

The objective of this study is to describe the daily variations of GEP, NEP, PAR and faPAR for white pine during the growing season (April 1 to October 31), and to calculate the LUE for white pine and describe the effect of stand age and drought on the trends in GEP, NEP and LUE over the course of six years.

Study area and data manipulation

Study area

The three plantation stands studied in this article are part of the Turkey Point Flux Station network located in southern Ontario, Canada (Figure 1). These stands are located within the boreal evergreen needleleaf and broadleaf deciduous forest transition zone (Arain and Restrepo-Coupe 2005). All three sites are composed largely of white pine (*Pinus strobus* L.) needleleaf vegetation (i.e., coniferous trees). These trees can live approximately 350 to 400 years and may grow as tall as 60 m. White pine is an important species in North America because of its ability to adapt to dry environments (Arain and Restrepo-Coupe 2005).

The youngest of the three plantation stands (TP02) was planted in 2002 on former sandy agricultural land with mostly flat terrain. It is located at 42.66° N, 80.55° W at an elevation of 265 m. The vegetation in this stand is 100% white pine. The middle-aged stand (TP74) was planted in 1974 and is located at 42.71°N, 80.35° W at an elevation of 184 m. TP74 was planted on sandy cleared oak-savannah land that is mostly flat with slight undulations. The vegetation cover is 94% white pine (*Pinus strobus* L.), 5% Jack pine (*Pinus banksiana* Lambert) and 1% oak (*Quercus* sp.). Lake Erie is 2 km south of the site. The oldest stand (TP39) was planted in 1939 on sandy cleared oak-savannah. It is located at 42.71°N, 80.36° W at an elevation of 184 m. The land is flat with slight undulations. In the winter of 2012, 30% of the trees in the stand were harvested as part of a thinning treatment to improve light and water availability (Thorne and Arain 2015). The trees in this location are 82% white pine (*Pinus strobus* L.), 11% Balsam fir (*Abies balsamea* (L.) Miller), 4% oak (Quercus sp.), 2% red maple (Acer rubrum L.) and 2% wild black cherry (*Prunus serotina* Ehrhart). TP39 and TP74 are located approximately 0.8 km apart and 17 km from TP02.

Data manipulations

Half-hourly GEP, NEP and PAR (incoming and outgoing) data were derived from eddy covariance measurements at the meteorological towers in three Turkey Point study sites. These 48 daily measurements were averaged to produce daily averages. GEP and NEP were recorded in µmol CO2 m^{-2} s^{-1} and then converted to g C (carbon) m^{-2} day^{-1}. Measurements of PAR were recorded in µmol (photons) m^{-2} s^{-1} and then converted to MJ m^{-2} day^{-1}.

Light use efficiency (LUE) calculation. LUE (g C MJ^{-1}) is the ratio of productivity (GEP) to the product of incident photosynthetically active radiation (↓PAR) and the fraction of ↓PAR absorbed by vegetation (faPAR) (Goerner et al., 2009; 2011; Moreno et al., 2012):

$$\text{LUE} = \frac{\text{GEP}}{\downarrow\text{PAR} \times \text{faPAR}}, \tag{1}$$

where for TP39 site,

$$\text{faPAR} = 1 - \left(\frac{\downarrow\text{PAR [2m]}}{\downarrow\text{PAR [28m]}} \right), \tag{2}$$

and for TP74 and TP02 sites,

$$\text{faPAR} = 1 - \left(\frac{\uparrow\text{PAR [top of canopy]}}{\downarrow\text{PAR [top of canopy]}} \right). \tag{3}$$

Figure 1
Map showing the locations of the three sites: TP02, TP74 and TP39 (image from Google Earth)

↓PAR refers to the downwelling PAR and ↑PAR is the upwelling PAR measured at the top of the canopy. The height of the top of the vegetation canopy at the site TP39 is 28 m (Equation 2). For TP74 and TP02 sites the height of the top of the canopy is less than 28m, therefore, ↑PAR and ↓PAR at the top of the canopy were used (Equation 3).

Results

Daily variation in GEP, NEP and PAR

Figure 2 shows daily values of GEP, NEP and PAR for the growing season (April to October) over the course of six years. The coefficient of determination between the daily values of GEP (g C $^{m-2}$ day^{-1}) and PAR (MJ $^{m-2}$ day^{-1}) for all years at TP02 is R^2 = 0.608. The R^2 value is 0.671 at TP74 and 0.604 at TP39. PAR data exhibit a distinct seasonal pattern, however, yearly PAR is relatively stable over six years at all the three sites; the only exception is at TP02 in 2013 (Figure 2). During this year, PAR is significantly lower than the rest of the years at the same site, as well as at the other two sites in 2013 by approximately 2.3 MJ m^{-2} day^{-1}. At TP02, the youngest stand, GEP can be seen to be increasing gradually by approximately 2.5 g C m^{-2} day^{-1} as the six years progress with the average GEP of 5.85 g C m^{-2} day^{-1}. At TP74, GEP increases by a lesser amount of 1.2 g C m^{-2} day^{-1} over the six years because this stand is more mature; the average value is 7.03 g C m^{-2} day^{-1}. At TP39, the GEP is gradually decreasing by approximately 0.2 g C m^{-2} day^{-1}, with values averaging 6.58 g C m^{-2} day^{-1}.

NEP in Figure 2 sits lower on the y-axis than GEP because GEP is equal to the sum of NEP and respiration (R):

$$GEP = NEP + R \tag{4}$$

As GEP and R increase in summer months, a decrease in NEP is observed. The GEP and NEP curves almost converge at the beginning and end of the growing season when respiration is slowly increasing or decreasing, respectively. Similar to GEP, NEP is also highest at TP74, the middle-aged site. The average NEP value over the six years at TP74 is 2.32 g C m^{-2} day^{-1}, compared to TP02 and TP39, which average 1.10 g C m^{-2} day^{-1} and 1.42 g C m^{-2} day^{-1}, respectively.

Seasonal variation is also apparent at the three sites, where the peak of PAR occurs in approximately June or July and the peak of GEP follows in August. This is because GEP is strongly dependent on light during the growing season when the temperature allows for growth (Falge et al. 2002). NEP is also strong-

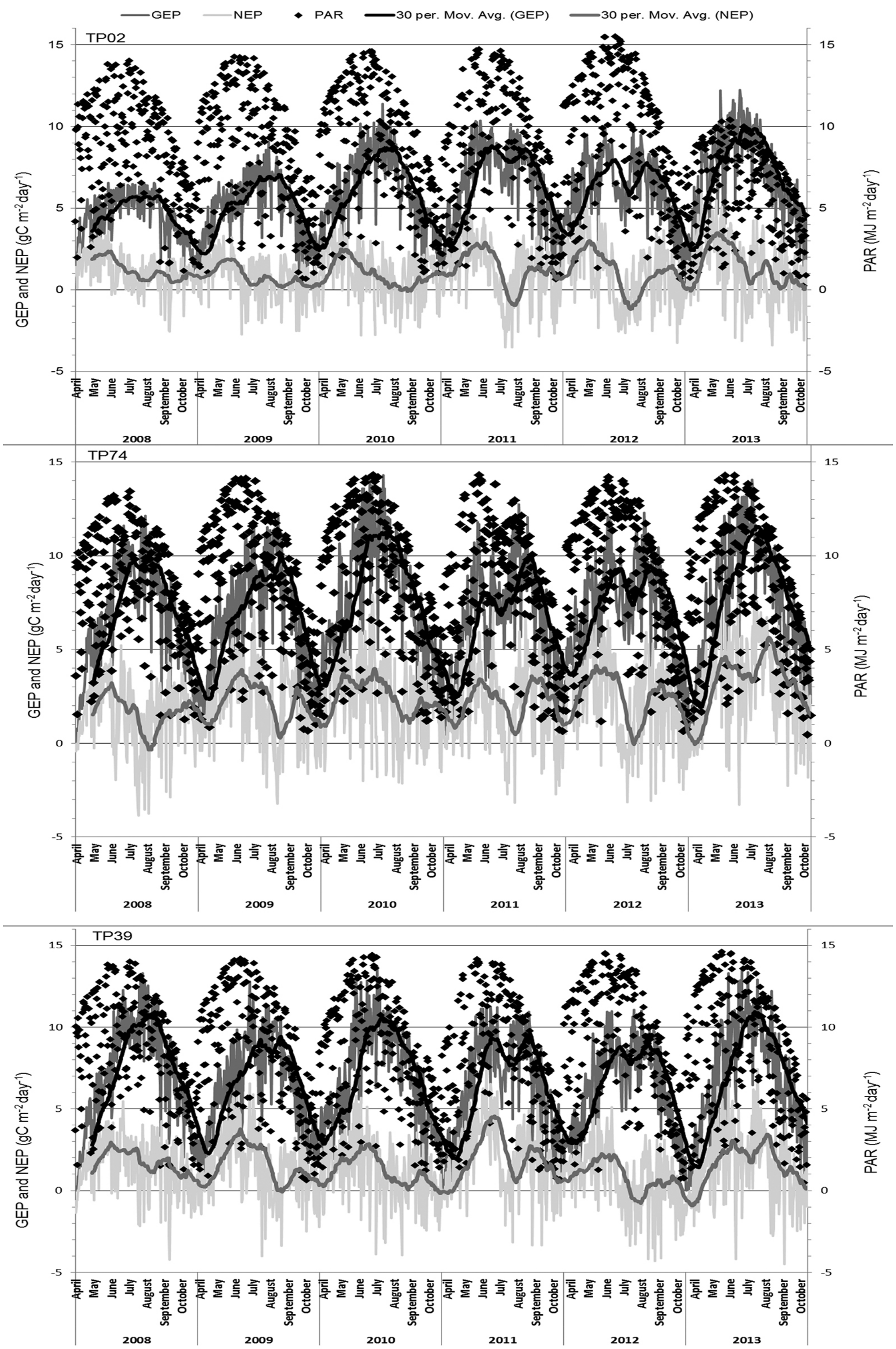

Figure 2
Daily values of gross ecosystem productivity (GEP), net ecosystem productivity (NEP), and photosynthetically active radiation (PAR) during the growing season (April to October) from the towers in TP02, TP74, and TP39 for 2008–2013

ly influenced by the length of the growing season (Falge et al. 2002) and is longer for conifers than for deciduous trees (Amiro et al. 2006).

Figure 3 presents the ratio of GEP to PAR at the three sites. At TP02, the trend is upwards because GEP increases by approximately 0.8 g C MJ^{-1}. Again, TP74 and TP39, the more mature stands, show less increase over time. TP74 increased by 0.25 g C MJ^{-1} and TP39 increased by 0.05 g C MJ^{-1}. Seasonal variation is once again shown in Figure 3, presenting a similar variation as in Figure 2. In TP74 and TP39, the seasonal variation is most prominent, peaking in the summer and dropping over the fall. The maximum values of the ratio were observed in summer. At TP39 in early 2012, one-third of the trees were cut down as part of a thinning treatment (Thorne and Arain 2015). The harvesting of the trees resulted in a decrease in GEP; the average GEP/PAR ratio in 2012 is 0.8 g C MJ^{-1} compared to the other years at this site which averaged 0.88 g C MJ^{-1}.

The faPAR values calculated from Equations 2 and 3 are displayed in Figure 4. faPAR measurement at TP39 is generally higher than at TP02 and TP74 and shows seasonal variation prominently. At TP74, the middle-aged stand, the faPAR averages 0.96, which is slightly higher than at TP02 where the average is 0.94. At TP39, the average is 0.97. At both TP02 and TP74, there were many gaps in the data which reduced the expression of seasonal variation when compared to that at TP39. At TP02 and TP74, missing values are recorded in 2008 and 2013. This resulted in curves that did not produce an easily recognizable pattern. TP39 had less missing data and therefore seasonal variation is visible.

Figure 5 shows the cumulative NEP values for each of the six years. At TP02, the peak year-to-year NEP values fall between approximately 110–225 g C m^{-2}. At TP74, the peak values range between 300 g C m^{-2} and approximately 650 g C m^{-2}. At TP39, the values have decreased in comparison to TP74 and lie between approximately 125 g C m^{-2} and 370 g C m^{-2}. The highest NEP was observed at TP74 on June 30, 2010 when maximum daily values were up to 8 g C m^{-2} day-1 followed by 7.4 g C m^{-2} day^{-1} on June 18, 2011 at TP39 and 5.5 g C m^{-2} day^{-1} on May 12, 2012 at TP02. NEP decreased sharply in the fall (September through October) especially at the TP02 and TP74 sites

Light use efficiency (LUE) and stand age effects

Related to the faPAR shown in Figure 4, Figure 6 displays the daily LUE values during the growing season calculated using Equation 1. Goerner et al. (2011) define LUE as the effectiveness with which an ecosystem uses absorbed photosynthetically active radiation to produce photosynthates which are recorded as GEP. At TP02, similar to the previous figures, a gradual increase is displayed which corresponds with the new growth and young age of the stand. This corresponds with Figure 2 and the growth that is displayed at TP02 over the first six years. The increase in LUE then would affect the increased GEP (or the photosynthates produced). Seasonal variation is not yet prevalent at TP02. In TP74, a seasonal pattern has evolved. LUE at TP74 peaks in approximately September each year. Similarly, TP39 presents a seasonal variation pattern, which also peaks late in the growing season in approximately September. In Figure 6, TP02 shows an increase in LUE over the six years of 0.75 g C MJ^{-1}. LUE increased by 0.25 g C MJ^{-1} at TP74 and by 0.02 g C MJ^{-1} at TP39.

Discussion

Effect of drought and stand age on GEP, NEP and faPAR

During the summers of 2011 and 2012, GEP and NEP decreases briefly at all three sites due to a drought (Figure 2). This corresponds with results from studies by Law et al. (2001), Barr et al. (2002), Asner et al. (2004), Arain and Restrepo-Coupe (2005) and Moreno et al. (2012) that reported GEP and NEP decreases in drought situations. Wen et al. (2010) stated that drought suppressed NEP by suppressing GEP and R.

In the summer of 2012, the water deficit was 0.4 for TP39 and TP74, and 0.3 at TP02. The drought persisted for almost two months (July and August). Based on the Palmer drought severity index (PDSI), Skubel (2015) reported that 2012 was the most notably dry year in the Turkey Point region. The seasonal cycle of PDSI showed negative values through the growing season, with the highest value of -2.5 in July. Similar observations were found by Sperry and Ikeda (1997), Claus and George (2005), and Warren et al. (2007) which indicated that young forests have smaller and shallow root systems than older sites, making them more susceptible to drought. As forests grow older, it develops a larger and deep root system to gain access to water during dry periods (Sperry et al. 2002). Stomatal pores may also close during severe drought and therefore inhibiting photosynthesis, GEP and NEP (Lorenz and Lal 2010).

Ryan et al. (2004) discuss factors such as nutrient limitation and increased abrasion between tree canopies that may cause a decline in GEP with age and state that while some factors may slow a decline in GEP, none will offset a decline completely. At TP39, it is noted that in 2012 the GEP is lower on average than the rest of the years at that particular stand. This is likely a result of the harvesting that occurred early that year as part of a thinning treatment (Throne and Arain 2015).

The GEP/PAR ratio is useful sign in studies of interannual variability (Valentini et al. 2000). Figure 3 presents the ratios of GEP to PAR from 2008 to 2013 at the three sites. The drought is also shown as a slight decline in the summers of 2011 and 2012 in the months of July and August at all the three sites (Figure 3). This is because GEP decreases in response to drought situations (Barr et al. 2002; Asner et al. 2004; Wen et al. 2010).

Moreno et al. (2012) state that faPAR is strongly influenced by canopy structure and green biomass. faPAR in evergreen forest ecosystems typically shows less seasonal variability than deciduous forests (Goerner et al. 2009; 2011; Moreno et al. 2012). At TP02, the faPAR sits slightly lower than at TP74 or TP39 (Figure 4), which corresponds with its younger age, suggesting that at a younger age, the trees in a stand cannot absorb as much light as older stands due to smaller canopy cover. Although leaf area index was not measured at the three sites, Skubel (2015) showed that reflected PAR decreased and photosynthetic capac-

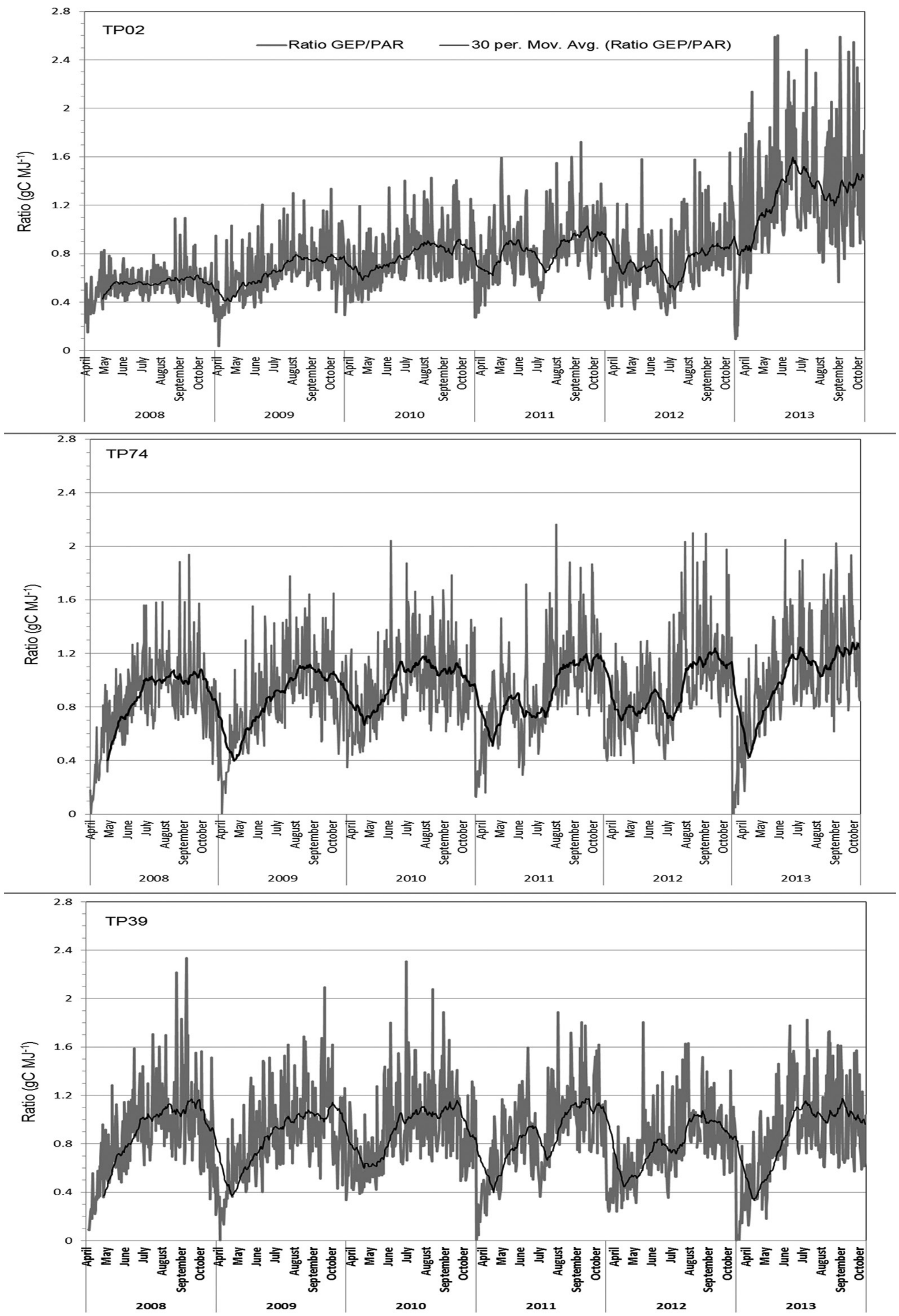

Figure 3
Ratio of GEP/PAR during the growing season for the three sites (Tp02, TP74, and TP39)

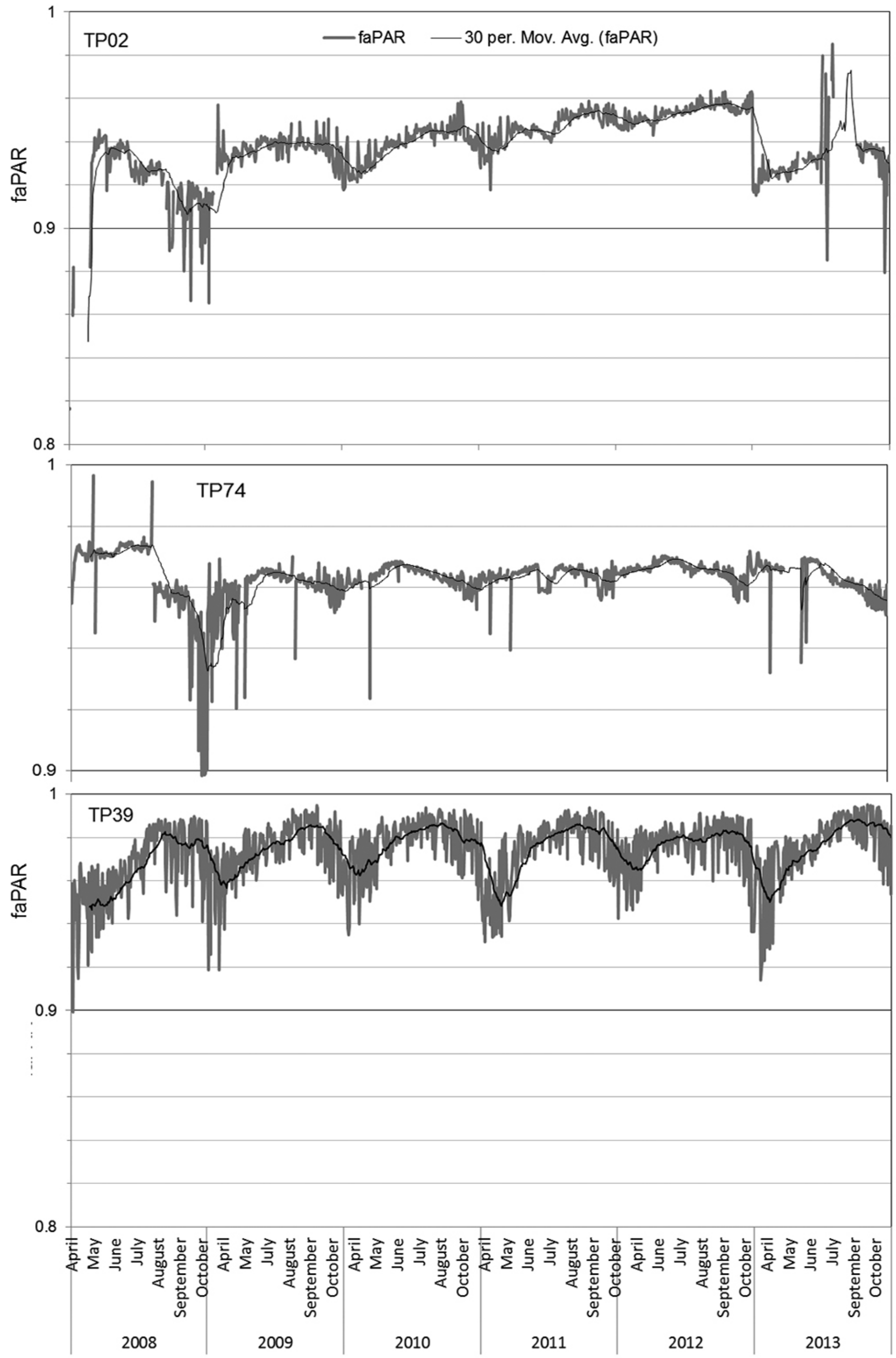

Figure 4
Daily faPAR (the fraction of incident PAR absorbed by vegetation) during the growing season for the three sites (Tp02, TP74, and TP39)

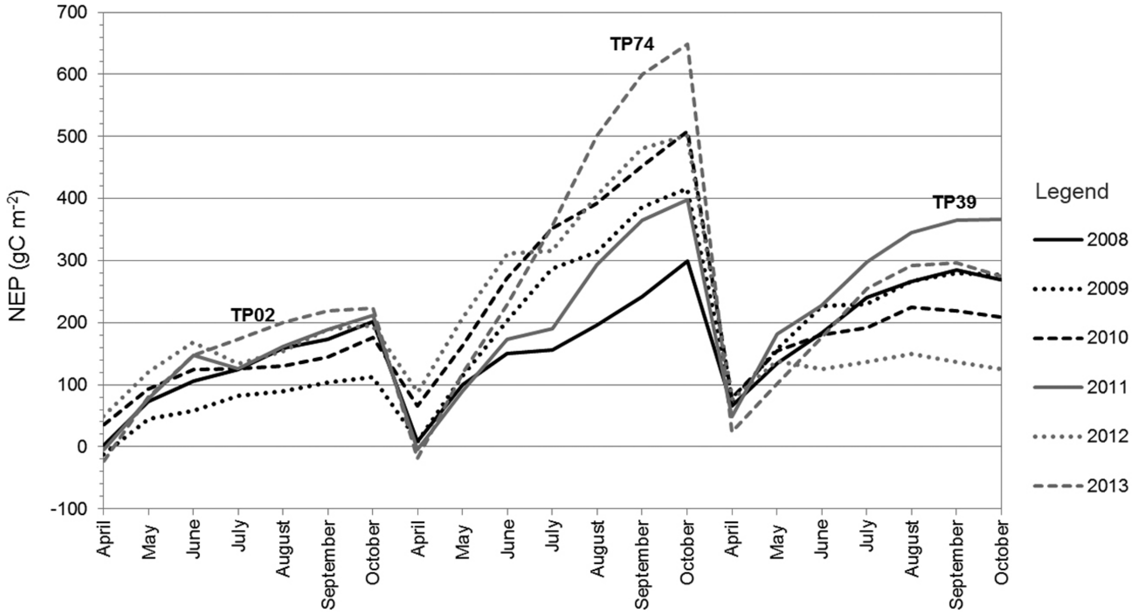

Figure 5
Annual cycles of cumulative net ecosystem productivity (NEP) at TP02, TP74, and TP39

ity increased at TP02 as the size and density of the canopy increased over the study period (2008–2013). The faPAR at TP39 dips during April and October and peaks in approximately July to August of each year. Binkley et al. (2004) and Gobron et al. (2005; 2007) suggest that in times of drought, faPAR will decrease. Also Chan (2016) noticed significant decreases in faPAR at TP02 caused by summer drought of 2012. This can be seen especially well at TP39 in the summer of 2012 where a slight depression occurs in the summer months (Figure 4). Drought reduces the vegetation growth rate and consequently its capacity to intercept solar radiation (Gobron et al. 2005). Further water stress can be created by an increase of the vegetation temperature due to the decrease of evaporative cooling.

The cumulative NEP peak at TP74 and TP02 in 2013 (Figure 5), was likely caused by high GEP values from the middle-aged and young stands compounded with increased vegetation canopy. A similar increase was described by Kljun et al. (2004; 2007) in an aspen stand; however, the same study stated that conifers were not severely affected by drought in the same way as deciduous trees. Positive values of cumulative NEP begin to appear in April at each of the sites; this signals the onset of the growing season (Arain and Restrepo-Coupe 2005). Positive NEP values continue each year until approximately beginning of November, which suggests a longer growing season that is typical of southern Ontario (Arain and Restrepo-Coupe 2005). Similarly long growing seasons were also reported by Falge et al. (2002) in six temperate conifer forests and Amiro et al. (2006) confirmed that coniferous trees have longer growing seasons than deciduous trees from the same region.

Interannually, differences in cumulative NEP at the three stands became prevalent in approximately May to June, similar to Krishnan et al. (2009) findings in Douglas fir. According to Delucia et al. (2007), stand age contributes to the decline in NEP; therefore TP39 should have lower NEP values than TP74, as shown in Figure 5. Arain and Restrepo-Coupe, (2005) agree that in plantation forests, GEP will decrease with stand age, which will result in a decrease in NEP as well. Ryan et al. (2004) and Skubel et al. (2015) also suggested that decreasing GEP is likely a cause of age-related decreases in NEP which corresponds with the decrease in GEP and NEP found at TP39. The decline in NEP in aging forests is primarily determined by GEP, which decreases more rapidly with increasing age than R does (Tang et al. 2014).

Light use efficiency (LUE) and stand age effects

LUE decreased with stand age, which suggests that younger stands have better light use efficiency than more mature stands (Figure 6). This corresponds with Ryan et al. (2004) who found that efficiency in the use of light declined with age in a eucalyptus plantation. Similarly, Martin and Jokela (2004) stated that LUE declined rapidly as stands aged. The decrease in light use efficiency with age occurs because of PAR saturation in the canopy. Arain and Restrepo-Coupe (2005) reported that at TP39 (the older site) LUE decreases when PAR increases beyond 11.3 MJ m^{-2} day^{-1}. Similar observations were found by Law et al. (2001), Anthoni et al. (2002), Falge et al. (2002) and Turner et al. (2003), which noted hyperbolic relationships between GEP and absorbed PAR at old forests due to PAR saturation and photosynthesis increasing approximately linearly with irradiance in young forests where the canopy is dense and a larger fraction of leaves are shaded. Therefore, light saturation occurs at lower PAR in the old forests than in young stands.

In 2011 and 2012 during the summer months, a decrease in LUE can be seen due to the drought conditions. Wu et al. (2010)

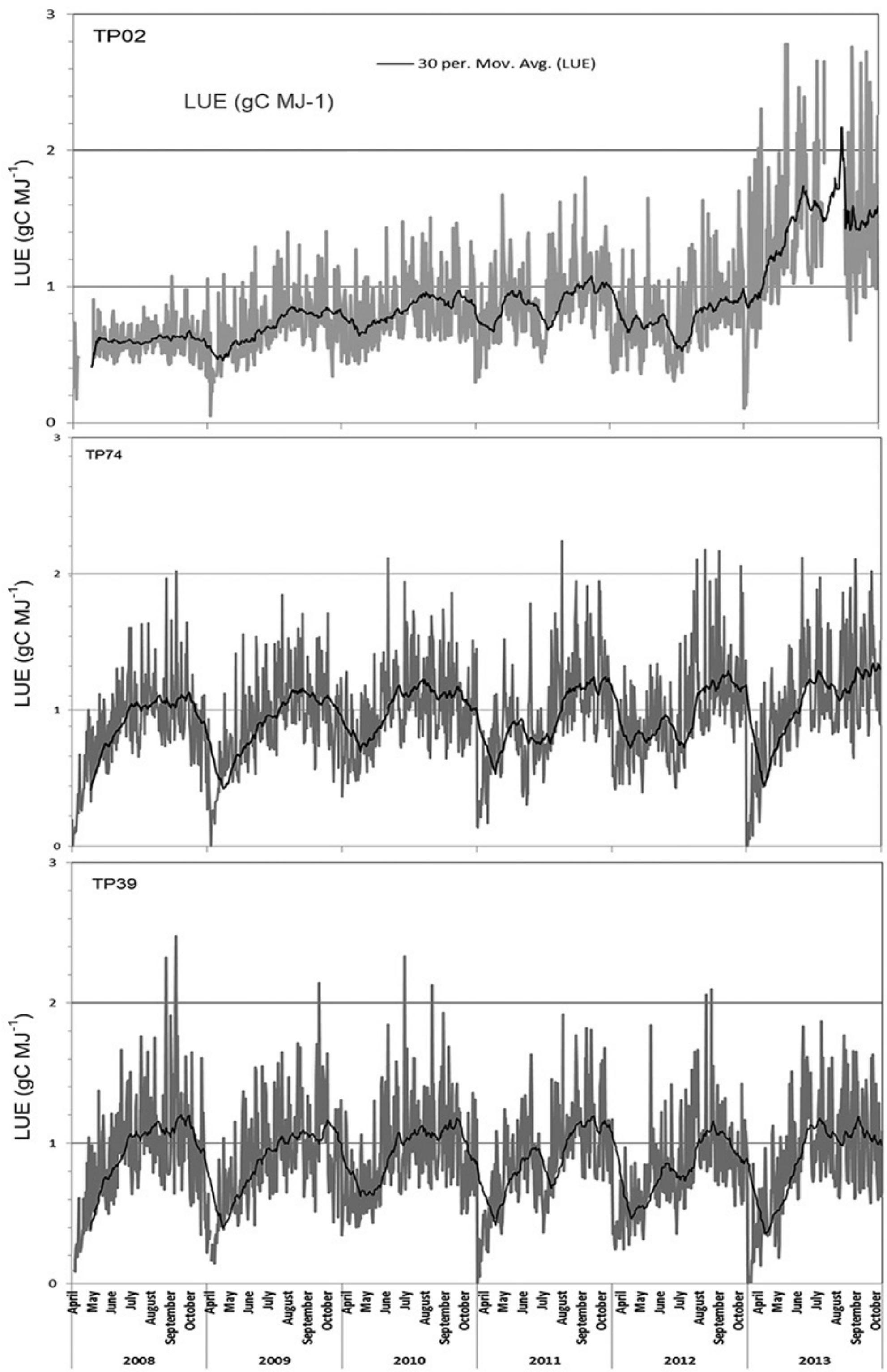

Figure 6
Daily light use efficiency (LUE) during the growing season for the three sites (TP02, TP74, and TP39)

and Moreno et al. (2012) also found similar results that LUE is affected by drought and will decrease in such conditions.

Conclusion

In this study, the daily variations of GEP, NEP, PAR and faPAR were presented for six growing seasons. These fluxes were used to calculate LUE and to describe the effects of stand age and the drought of 2011 and 2012 on trends in GEP, NEP and LUE over the six years.

The PAR data showed a distinct seasonal pattern. However, yearly PAR was found to be mostly constant for the duration of the study at all of the sites with one exception at TP02 in 2013 where PAR decreased. GEP and NEP peak in middle-age stands and decrease in older stands. GEP at TP02 gradually increases over the six years as the stand matures. The relationship of GEP and NEP depends on the values of R, which are affected by temperature and water availability. Therefore, the relationship between GEP and NEP varies seasonally and is affected by local weather events, such as drought. During drought, GEP and NEP decreased due to reduced vegetation growth rate and lower respiration.

The faPAR values were found to increase as the stands aged, increasing from 0.94 at TP02 to 0.97 at TP39. Seasonal patterns were difficult to deduce at TP02 and TP74 due to missing data. However, at TP39 faPAR clearly peaked during summer months and decreased in spring months.

LUE and GEP are related in Equation 1 with LUE following the pattern shown for GEP at all three sites. At TP02, as the stand was maturing, the LUE increased over the six years. LUE was stable and at its peak at TP74, and was stable but decreasing at TP39. These observations mean that LUE decreases in plantation stands over time. Age also affected GEP and NEP which both generally decrease as stands age.

Studying the whole year of flux measurements would be beneficial, especially in stands with coniferous trees which typically display longer growing seasons than deciduous trees in the same region. While the proximity of the stands used in this study may have a regional bias, similar studies could be reproduced in different regions with different species in order to compare results and develop a larger understanding of LUE and stand age effects.

Acknowledgements

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Optimizing co-benefits of the urban forest using a GIS-based urban forest benefits model

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A GIS-decision support tool called the Urban Forest Benefits Model (UFBM) is discussed. The model provides decision makers, municipal planners, and urban foresters with the ability to prioritize their greening efforts so as to maximize the net environmental, economic and social co-benefits to their community. The model's focus centres around a spatial technique developed in this research that maximizes the co-benefits of trees as they relate to land use. There were three key objectives associated with this research: (1) to develop an inventory and framework of urban forest benefits calibrated for a specific city; (2) to develop a prioritized list of the city's sustainability goals and identify how greening efforts contribute toward these goals; and (3) to develop the GIS-based UFBM that will assist with the sequencing of greening activities (planting, maintenance, and protection) in order to optimize community co-benefits and attain long-term sustainability goals. Seven tasks were chosen for a customized case study application in Thunder Bay, Ontario, a medium-sized, cold-climate city. The combination of these tasks identified priority sites for strategic greening investments in Thunder Bay. The UFBM provides a new model for managing urban forests and is customizable and designed for use in other jurisdictions.

Keywords: urban forestry, sustainability, GIS, planning, benefits, green infrastructure

Introduction

Urban trees are commonly referred to as 'green infrastructure' because they provide a benefit to society similar to other 'hard infrastructure' (e.g., benches, culverts, roads). Studies focused on green infrastructure and its benefits are providing communities with an understanding of the value of urban forests, and are demonstrating green infrastructure's contributions toward more sustainable urban environments. A dramatic increase in land pressure and other urban problems in Canada and the US have provided a platform on which to showcase the value of green infrastructure in cities. Over the past three decades, urban forests have been shown to provide significant solutions to urban challenges such as mitigating the effects of urban sprawl and social inequalities, reducing stormwater runoff and water management costs, moderating microclimates, calming traffic, stabilizing and denaturing air and soil pollutants, and reducing noise (Dwyer et al. 1992; Bourne 2000; Pulford and Watson 2003; Li et al. 2005; Day and Dickinson 2008; Escobedo and Nowak 2009; Morani et al. 2011; Norton et al. 2015). Increasingly, using both social and applied research approaches, a wide range of the environmental goods and services produced by urban forests are being quantified (Dwyer and Miller 1999; Nowak and Dwyer 2007; Wolf 2008).

Maximizing the net level of benefits from trees in urban areas has long been a focus of concern for professionals and researchers (Clark et al. 1997). Commonly, higher levels of benefits can be achieved when a tree's structure is altered in a man-

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ner that results in more leaf area (Nowak et al. 2008). More leaf area, for example by providing the conditions and care to allow trees to mature and increase in size (Nowak et al. 2008). Larger, fuller trees have more leaf area, which allows them to perform more services like filtering air, cooling hot urban areas, capturing rainfall, and stabilizing soil. Suitable tree species and microsite selection also influence the level of net benefits provided.

Although under studied, the spatial placement of trees is another variable influencing a tree's ability to perform multiple-functions and thus significantly increase co-benefits to be gained by a single tree at one location. Depending on the spatial positioning of green infrastructure and its proximity to certain land-use classes (e.g., commercial, residential), its benefits can be maximized and targeted toward the needs of a community. While studies and models (e.g., i-Tree Tools) focusing on urban forest benefits have existed for nearly two decades (Dwyer and Miller 1999; Nowak et al. 2002; Nowak et al. 2008; Wang et al. 2008; Kirnbauer et al. 2009), few models have used geographical information systems (GIS) to optimize the multi-functional benefits of urban forests.

The Urban Forest Benefits Model (UFBM) involves a variety of elements that make it unique in comparison to existing models. First, the UFBM is highly adoptable and relevant to both small and large communities even those with limited urban forest budgets. Second, the model is simple to apply as it involves just three main stages. It uses a group/stakeholder process and other interdisciplinary methods that can process social benefits efficiently. Third, the UFBM creates priority maps (outputs) that have a fine enough resolution and contain information relevant to arborists and field staff, and can integrate long-term community and sustainability goals. The methods used within the UFBM to develop these priority maps are based on urban forest services and are derived, in part, from frameworks such as the Forestry Opportunity Spectrum (Raciti et al. 2006) and other urban tree canopy (UTC) studies (e.g., Locke et al. 2010). The priority maps are presented through the development of two indices—the Maintenance Index (MI) and the Planting Index (PI). The Maintenance Index identifies priority sites throughout a community that need maintenance and protection investments to allow for the continued provision of multiple key services by trees. The Planting Index demonstrates spatially where trees should preferably be planted to optimize the predetermined co-benefits to a community.

Project objectives and background

As indicated above, the UFBM uses GIS to prioritize locations for tree planting and tree maintenance activities in city forest locations. The UFBM aims to dramatically enhance the co-benefits derived from trees by identifying locations that allow green infrastructure to be as multi-functional as possible. It also targets important land-use areas that allow urban forest services to compliment and support intended community planning goals. The model evolved out of the need to understand how urban forests might be better integrated into community planning strategies to alleviate the existing sustainability problems faced by cities. The UFBM developed in this research is unique in comparison to other models mentioned earlier as it integrates the mitigating, multi-functional goods and services of trees with the sustainability objectives tailored or customized to a specific community and explicitly uses GIS to highlight priority areas.

The UFBM is a combination of computer-based (GIS) and non-computer based (focus groups) components used to prioritize greening investments at a neighbourhood scale in a manner that maximizes the biophysical and socioeconomic returns to the community. Additionally, it provides urban planners and urban foresters the means to demonstrate where trees can help simultaneously achieve a variety of community sustainability objectives (e.g., climate change adaptation, mitigation of stormwater runoff, and increase in active transportation). Active transportation "refers to any form of human-propelled transportation such as walking, cycling, using a wheelchair, in-line skating or skateboarding" (Government of Canada 2017) and is increasingly the focus of planning efforts at improving community and personal health (e.g. City of Thunder Bay 2016).

This article discusses the conceptual approach in developing the UFBM and its application to Thunder Bay. There are three key objectives associated with the research: (1) to develop an inventory and framework of urban forest benefits calibrated to the case study city; (2) to develop a prioritized list of Thunder Bay's sustainability goals and identify how greening efforts contribute toward these goals; and (3) to develop spatial greening schemes using GIS that will sequence planting, maintenance, and protection efforts in order to optimize community benefits and attain long-term community sustainability goals. In meeting the third of these objectives the article presents two GIS based index models—the Maintenance Index and Planting Index.

Study area

Thunder Bay is a small to medium-sized city with a metropolitan population of approximately 121,600 (Statistics Canada 2017), located in Northwestern Ontario. It has a total land area of 2,556 km^2 and an average population density of 47.6 persons/km^2. Thunder Bay was created in 1970 through the amalgamation of the two former cities of Port Arthur and Fort William, now commonly referred to respectively as the North Core and South Core (Figure 1). Over the past few decades, Thunder Bay has faced many urban challenges similar to those of large urban centres in Canada and the US, such as urban sprawl, economic decline, and the decay of downtown and inner city neighbourhoods. Unique to Thunder Bay is the existence of two struggling downtown cores, amidst the backdrop of the loss of well-paying blue collar employment in the forestry and grain-handling sectors since the 1990s. The economic activity that once thrived in the two downtown cores has been directed to a new focal point in the Intercity area and is meant to bring the two cities together both physically and economically (Randall and Lorch 2007; EarthWise Thunder Bay 2008).

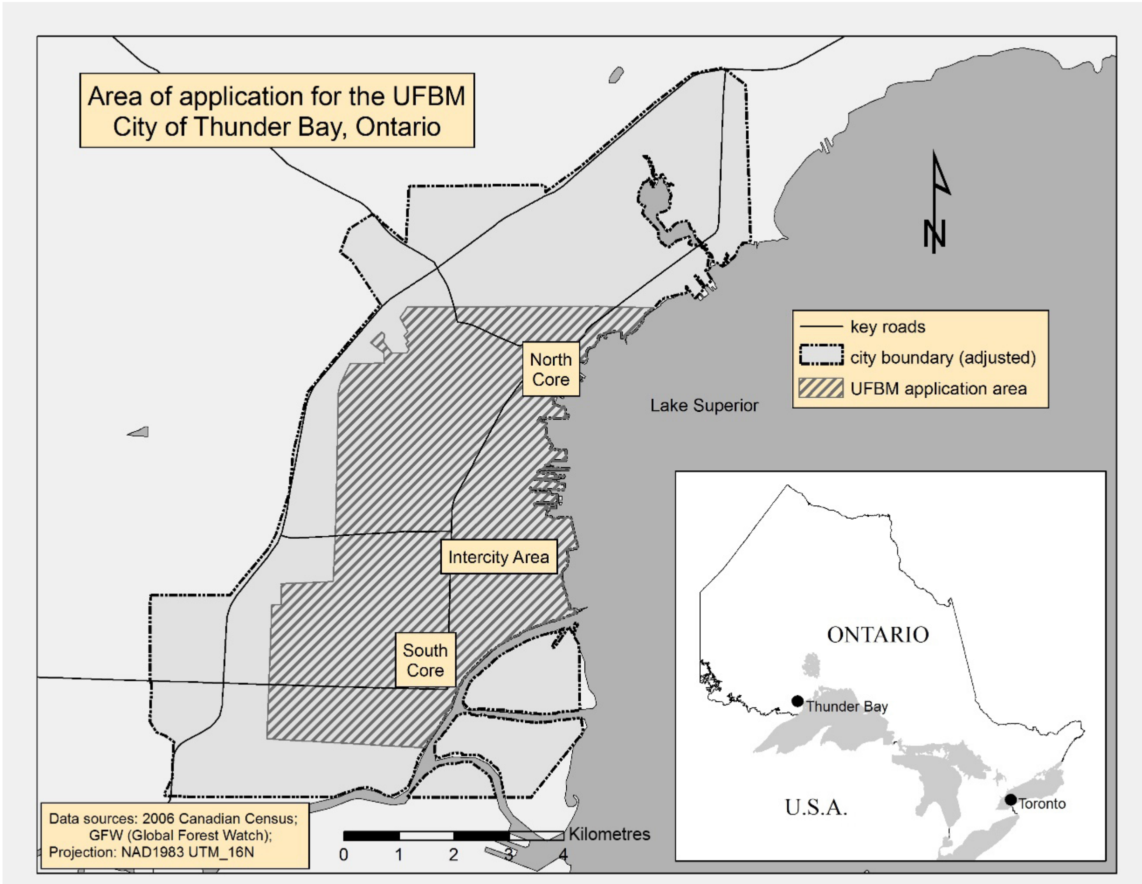

Figure 1
The area of application of the UBFM in Thunder Bay

Thunder Bay was an ideal location for the case study due to its array of social, economic and environmental challenges. It was also selected because the lead author has firsthand experience working as an urban forest professional at the City of Thunder Bay and is familiar with the city's tree inventory and related datasets required for this research.

Conceptual model: Methods and data requirements

The primary objective of the Urban Forest Benefits Model (UFBM) was to identify urban sites for greening that would provide the greatest positive impact to the community–this impact being an aggregated index of the numerous socio-economic and environmental benefits available from an urban forest. The conceptual approach of the developed UFBM consists of three main stages (Figure 2), and provides the methods and framework required to replicate the model in other jurisdictions. The 'standard tasks' within the model are those informed by current practice and professional urban forestry literature, while the 'link table' tasks are those included for the Thunder Bay case study. Other cities would be able to develop other 'link table tasks' based on their own needs developed through the focus group process. The next section describes the methods employed within the developed conceptual model (i.e., Stages 1 to early Stage 3 in Figure 2). The aggregated results in the formulation of two indices—the Maintenance Index and the Planting Index (i.e., end of Stage 3 on Figure 2)—are discussed later in the results portion of the article.

Focus groups

Focus groups and group interviews are effective and innovative methods of generating wisdom in complex research environments (Morgan 1996; Gibbs 1997; Beckett et al. 2000). For example, by utilizing the pooled knowledge of a group of experts, a researcher can avoid the costs of duplicating primary research of forest benefits that has been developed elsewhere. The development of the UFBM involved the use of two focus groups (i.e., Stage 1 in Figure 2). Based on the compilation of urban forest benefits found in the literature, a first focus group was created comprising local professionals and experts in the fields of urban forestry and landscape architecture. The discussions of this focus group provided a stronger sense of certainty regarding the urban forest functions that clearly benefited the community —an important first step which determined if and how the multitude of benefits documented in the literature apply in Thunder Bay.

A second focus group identified and ranked the sustainability goals of the City that would ultimately be used in the link

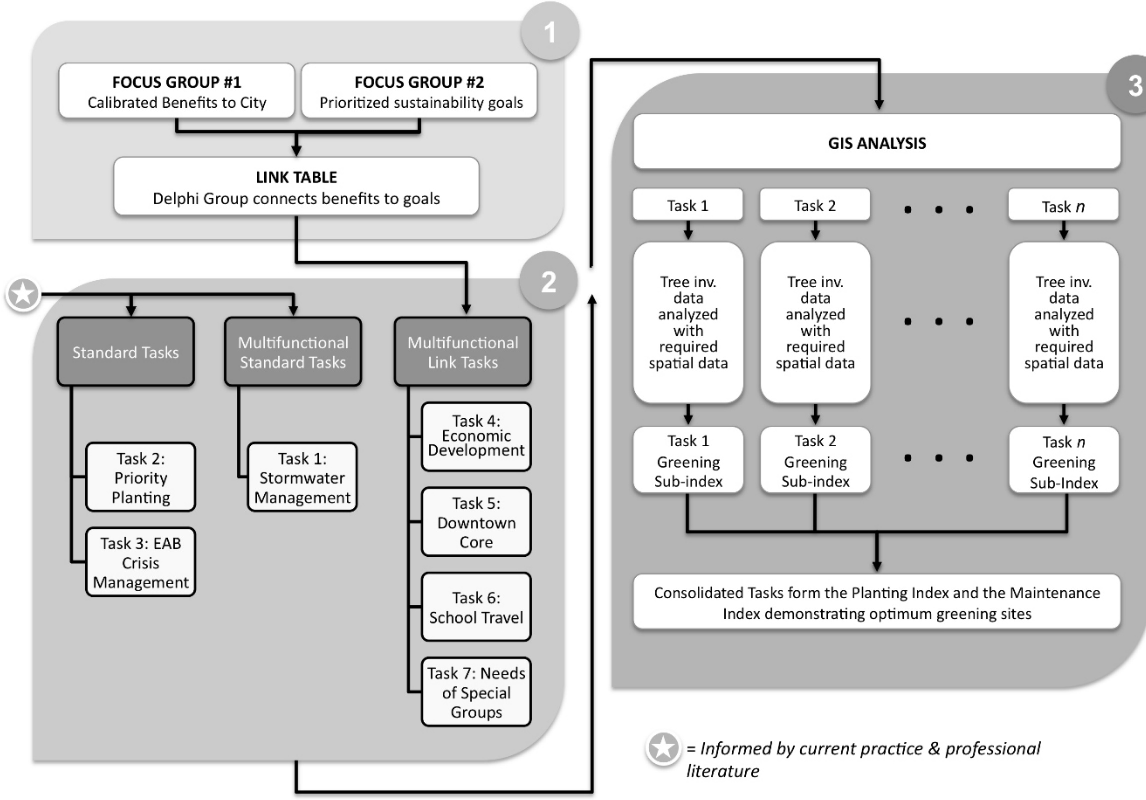

Figure 2
The conceptual model of the UFBM is comprised of three stages: 1) focus group and link table development, 2) task identification, and 3) GIS analysis and consolidation of tasks. A GIS model was developed for the seven listed tasks resulting in the identification of 'hot spots' or priority locations for tree planting, maintenance and protection.

table discussed below. This focus group comprised of senior administrators and other professionals, such as city managers, community decision makers (e.g., health unit, active transportation), and urban planners, provided a holistic perspective needed for this step of the model. Prior to the second focus group meeting, a literature review of the City's major guiding documents was completed in order to identify the core goals and direction of the City that pertain to sustainability. Various documents were used, such as the Thunder Bay Official Plan (City of Thunder Bay 2005), the Community Environmental Action Plan (Earthwise Thunder Bay 2008) and the Mayor's Strategic Plan (City of Thunder Bay 2007). Although other plans exist within the community, these three were chosen because of the broad range of people and comprehensive set of goals they represent, including their foci on subjects like education, the environment and public health.

In reviewing the above guiding documents, those sustainability goals of the city having potential to be supported by an urban forest benefit (as substantiated by the literature) were selected and compiled in a tabular framework. For example, if a particular air quality improvement goal could be fully or partially accomplished by the services of an urban forest it was included in the framework. Each goal summarized in the framework was classified on the basis on sustainable development principles into one of three categories, namely (1) social capital, (2) environmental capital, and (3) economic capital. A ranking exercise was then carried out with the second focus group to establish a level of priority for the community with regards to the sustainability goals identified in the framework. Creating a calibrated list of urban forest benefits and a priority list of sustainability goals was essential in order to complete the link table process, that is, to isolate a set of achievable forest management tasks that would address specific sustainability goals of the City.

Link table

The link table within the UFBM is a comprehensive process that included the use of a Delphi group to measure the level of connection, however small or large, between an urban forest benefit and a particular sustainability goal (Table 1). For example, a goal of increasing active transportation in a community is influenced by the ability of trees to beautify the neighbourhood, to reduce noise, to calm traffic, and to protect pedestrians. The link table provided a means of identifying the benefits that most strongly contributed toward a particular sustainability goal. If a

Table 1
Link table showing extent of agreement or disagreement about connections between urban forest benefits (column headings) and sustainability goals (row headings)

Extent of Agreement

1 - strongly disagree
2 - disagree
3 - possibly agree
4 - agree
5 - strongly agree

		← Benefits →					
		Trees make corridors more attractive and appealing and connect a community with the locality	Trees positively affect tourism through influence on consumer behaviour and beautification	Trees lead to temperature reduction and other microclimatic effects	Trees attract business investment through increased aesthetics and through increased traffic/tourism	Trees provide corridor between roads and sidewalks protecting pedestrians and giving the perception of safety	Trees control erosion especially on steep areas and maintain stability on slopes
	Summary Benefit →	Sense of Place	Tourism	Air Temp / Microclimate	Attract Business Investment	Pedestrian Safety	Erosion and Slope Stability
	Benefit Category →	Beautification and Design	Economic Development	Air Quality	Economic Development	Public Health And Safety	Lands
	Benefit Section →	Social Benefits	Social Benefits	Biophysical Benefits	Social Benefits	Social Benefits	Biophysical Benefits
Sustainability Goals — **Goals Selected by Focus Group**							
Economic Development	Support the creation of a positive climate for business, institutions and employees in order to develop a diversified growing economy; city will rely more on secondary and tertiary support industry, retail and service functions, and small business, rather than the traditional sources of employment	**3**	**4**	**5**	**5**	**5**	**2**
Downtown Core	Maintain and enhance the downtown areas as unique focal points of activity, interest and identity for residents and visitors through the provision of the fullest range of urban functions and amenities	**4**	**4**	**4**	**3**	**4**	**2**
Intensification / Housing	Encourage efficient residential land use within the city by facilitating the creation of new residential accommodation within existing buildings or on previously developed serviced land	**2**	**2**	**3**	**3**	**3**	**1**
Needs of Special Groups	Encourage consideration of the needs of special groups, and in particular persons with disabilities, in the design and construction of buildings and other facilities	**4**	**1**	**4**	**2**	**3**	**1**
Active Transportation (AT)	Improve the number of people walking, biking, or travelling by other human-powered means	**3**	**2**	**5**	**2**	**3**	**2**
Open Space Areas	Achieve a highly integrated system of recreational areas and trails thoughout the city	**1**	**1**	**5**	**1**	**3**	**1**
Green Building	Achieve long-term savings to the citizens of Thunder Bay through reduced operating and life-cycle costs of municipal and private facilities	**1**	**1**	**5**	**1**	**1**	**2**

particular connection was strong (i.e., a particular sustainability goal of a community can be, in part or in whole, accomplished through the function of an urban forest), then a link table process identified this connection as a 'multi-functional link task' that was then modeled using GIS to influence greening activities and maximize benefits. The link table process focused on the most urgent sustainability aims of a community and provided a balanced approach to sustainability, by choosing an array of tasks that focus on the economic, social, and environmental aspects of city living. The link table, an example of which is shown in Table 1, contained over 30 sustainability goals and 50 benefits. As mentioned earlier, the Delphi group helped to confirm the strengths of the key linkages between the sustainability goals and potential benefits derivable from the urban forest. In this case study, the members of the Delphi group were drawn from the education, environment, public health and urban forest sectors.

Compiling tasks

The second stage of the UFBM identifies the various standard tasks and link table tasks selected (Stage 2 in Figure 2). Each of these tasks is represented by a spatial greening regime, that is, a map that prioritizes greening activities in order to accomplish a particular sustainability goal (e.g., air pollution reduction, traffic calming). The UFBM is comprised of three task categories, namely multi-functional link tasks, multi-functional standard tasks, and standard tasks. The term 'multi-functional' denotes that the task can be used in the model with other tasks to identify sites where trees perform multiple key functions and produce higher net benefits. The advantage resulting from multi-functional tasks are that they can be stacked on top of each other in a spatial environment in order to identify those locations with maximum co-benefits and are here referred to as 'spatially optimized services'. The term 'standard' denotes that the task is a commonly applied management activity performed by a manager of the urban forest. These standard tasks include routine greening (planting, maintenance and protection) strategies which may have been employed in a community prior to their using the UFBM, such as targeting new housing developments for planting, or for tree replacements due to emerald ash borer damage. For example, if a community routinely managed their urban forest to mitigate stormwater effects, such a task would be considered a standard multi-functional task. The standard tasks for this study were determined through consultation with the City of Thunder Bay's city forester as a subset of those routinely used urban forest management practices.

GIS analysis

A GIS model was developed for each of the standard and multi-functional tasks in the UFBM, resulting in the identification of 'hot spot' maps (or priority locations) for increasing or protecting existing leaf area. Each task was modeled individually using ESRI's ArcGIS software and employed a grid of one-hectare pixels to define the forest management areas of the city. A one-hectare resolution was deemed to be large enough to present a broad overview of the city while providing small enough management areas for onsite planning and design. This resulted in an independent set of maps demonstrating recommended locations to plant, maintain and protect trees to ensure optimal levels of leaf area and benefits to the community were achieved. These maps were then combined to form a final comprehensive map demonstrating optimum locations for greening.

The analysis required for each task was determined by the type of task and the available data, but in most instances followed a common methodological approach as generalized in Table 2. Since the standard and multi-functional tasks incorporated a broad array of social, economic and environmental issues (e.g., planning for children's journeys to and from school, planning for special needs groups), the required data were similarly broad. For example, completion of the stormwater standard task required a variety of data such as public and private tree cover, impervious and pervious cover, and aerial imagery. From these inputs, analysis was performed to determine problematic stormwater areas, and ultimately to demonstrate areas that would benefit from increased tree care, protection or planting to enhance existing tree cover. Other tasks needed details on business or school locations and census data. With respect to a set of steps within a given task, if an adequate methodology already existed in the literature and was found to be suitable, for example Nowak et al.'s (2002) Priority Planting Index, it was used in the UFBM. If no methodology existed, one was developed. A general methodology for each task is found in Table 2.

Table 2
A general GIS methodology used to determine priority greening areas for each task

Step	Description
1. Identify the task.	Identified through various methods in Stage 2 of the conceptual model (Figure 2).
2. Explore the variables that could be used to determine and fulfill the task.	Explore the possible variables and types of data inputs required for the task (e.g., population density, business locations, tree cover). Use existing methodologies if available.
3. Select the variables and prepare the data.	From the list of all possible variables that influence the task, select the variables that can be supported by the data that is available.
4. Choose methods and tools.	Choose the methods and tools to perform the necessary measures to identify greening locations based on the selected variables.
5. Display the data on the map or perform analysis (if required).	Using GIS, the data for each criterion are represented on the map (e.g., business and school locations). Depending on the type of data and the criterion, analysis may also be needed using ArcGIS tools.
6. This step is reserved for the final compilation of all tasks together to identify priority greening locations.	Using the weighted linear combination method to assign weights to each task (according to Focus Group Two) to identify areas where the urban forest will simultaneously attain multiple benefits within a community.

Figure 3
A screen capture from ArcGIS® displaying the public (dark green) and private (light green) trees after the buffers had been applied, to produce a realistic representation of canopy cover based on each tree's crown width class

Measuring existing tree cover

Key to the development of the Planting Index (discussed below) was an up-to-date tree inventory of both publically and privately-owned trees. An updated inventory of publically-owned trees was acquired from the City of Thunder Bay while the extent and distribution of privately-owned trees were inventoried via remote sensing using ERDAS' Stereo Analyst and ESRI's ArcGIS. The private trees included those in the front, back and side yards of individual properties as well as forest stands (i.e., collections of trees located in relatively unmaintained environments within the city) (Figure 3). Two sets of high-resolution aerial imagery were acquired for the study area. The Ontario Ministry of Natural Resources provided 40 cm resolution near-infrared ADS40 imagery (leaf-off) and the City of Thunder Bay provided visible spectrum SID 20 cm QUAD (leaf-on). Both sets of imagery were flown in 2008 and provided a strong aerial image bank needed for the inventory. The following attributes using Stereo Analyst were collected for each privately-owned tree: tree location, visible canopy width (class), and tree type (conifer or deciduous).

Results

The UFBM as conceptualized earlier was applied using a case study approach for Thunder Bay. In this conceptualization, a total of seven management tasks were identified (Figure 2) including three standard tasks and four link table tasks. A fuller description of the seven tasks is provided below, including a rationale for their inclusion in the UFBM and the variables used to model their potential benefits. The results from each of these tasks are combined as two indices—the Maintenance Index and the Planting Index.

Tasks chosen for the case study application

Stormwater. The stormwater multi-functional standard task was selected to produce a priority greening planting scheme to reduce the peak, volume, and rate of stormwater runoff by targeting the highest concentration of impervious cover in Thunder Bay. This task focused primarily on environmental and economic capital. It was chosen because large tracts of impervious cover, combined with a network of drainage infrastructure designed to carry stormwater long distances, have created a host of water quality and maintenance issues for municipalities (Dwyer and Miller 1999; Goonetilleke et al. 2005), including Thunder Bay (North Shore Remedial Action Plan 2011). Trees capture rainfall and reduce runoff, and create favourable soil conditions that allow rainwater to permeate into and replenish groundwater (Wissmar et al. 2004). In addition, trees reduce the amount of pollutants entering streams and rivers, increase the quality of aquatic habitats, and ultimately replace or minimize the need for expensive hard infrastructure to manage the runoff (Dwyer and Miller 1999; Nowak 2006; Mullaney et al. 2015).

Priority Planting Index. The Priority Planting Index (PPI) is an index developed by researchers at the US Forest Service Northeastern Research Station (Nowak et al. 2002). It ranks tree planting locations based on population densities, tree stocking, and trees per capita. The intended results lead to a priority planting scheme to increase tree cover so as to benefit the greatest number of people. Many municipalities have used the PPI since its conception, providing recommendations for targeting planting locations in highly populated areas. Due to its wide acceptance and use by large and small municipalities alike, and its application in a variety of studies (Raciti et al. 2006; Morani et al. 2011), it was included in the UFBM as a standard task.

Emerald ash borer crisis planning. This standard task was selected to reduce the impact of ash loss once the emerald ash borer (EAB) (*Agrilus planipennis*) reaches Thunder Bay .Planning involves prioritizing schemes to increase greening activities in areas with high concentrations of ash cover and where no insecticide treatment would be prescribed for the ash. The task is to infill high concentration areas of present ash tree populations to offset the loss of tree cover and associated benefits in the near future. It was chosen primarily because the EAB is an invasive, non-native beetle and has been identified as one of the most destructive forest insects ever to invade North America (Province of Ontario 2014). The beetle is approaching Thunder Bay and the threat of extensive damage to the city's ash tree population is real and significant (Vescio 2010).

Economic development. The economic development multi-functional link task was chosen to produce a priority-greening scheme based on business density that could increase tree cover so as to benefit the greatest number of businesses across Thunder Bay. It was also chosen as it is recognized that urban vegetation can support the well-being of people and stimulate urban business districts (Wolf 2004a; 2005; 2008; Yanick et al. 2010). Trees can help mitigate the effects of negative moods and stress, which are commonplace among shoppers and business people (Gullone 2000; Joye et al. 2010). They can impact consumer purchasing behaviour in a positive manner and increase the work ethic and productivity of business people. Wolf and others have concluded that greenery enhances the perceived aesthetic qualities of urban areas and the appeal of commercial/retail districts (McPherson et al. 2006; Velarde et al. 2007; Wolf 2008; Joye et al. 2010).

Downtown core greening. This multi-functional link task was chosen to increase tree cover so as to benefit the greatest number of businesses and people in Thunder Bay's two downtown cores, and to ultimately help establish more attractive, functional, and prosperous downtowns. Trees play an important role in improving the aesthetics of downtown neighbourhoods. Their presence in business areas can stimulate value and the perception of value, and can provide a welcoming facade to attract customers and tourists (Wolf 2006). In Thunder Bay, the downtown cores are arguably more important than other areas of the city in stimulating the growth and health of the business sector. This is because healthy, vibrant downtown cores are significant assets and are essential for the life of communities (Jacobs 1961; City of Thunder Bay 2005).

Children's journey to and from school. This multi-functional link task was chosen to identify the need for additional tree cover along Thunder Bay roads to benefit and encourage children to walk or bike to school. It was chosen because trees play a significant part in growing strong healthy communities that embrace a culture of active-commuting to and from school (Wolf 2004b). This index was an attempt to help prioritize greening activities so as to benefit the largest number of people who walk and bike to school. It also serves as a means to encourage and increase active-commuting rates in youth who live close to schools. The direct and indirect benefits provided by green infrastructure, most notably trees, in regards to commuting by active transportation are numerous. One of the strongest forces is an increase in streetscape aesthetics. Beautified streetscapes are more attractive and are used more frequently by pedestrians (Wolf 2004b). The more people actively commute on a street, the more people use that street, and the safer the street becomes. The safety of children also increases through the integration of trees that safeguard youth from traffic while functioning as traffic-calming devices (Wolf and Bratton 2006). As pedestrian traffic increases, so do social interactions among neighbours and their community. These kinds of social interactions are valuable for the development of children (Taylor et al. 2001).

Trees also affect the biophysical environment and can lead to a variety of benefits for youth as pedestrians. Trees moderate the extreme temperatures in both summer and winter and provide shade from harmful UV rays (Raciti et al. 2006). The air and noise filtering capacity of green infrastructure can also be significant (Beckett et al. 2000; Escobedo and Nowak 2009) and creates more pleasant and healthy routes to and from school. Consequently with an increase in active transportation, the number of cars and congestion on roads and associated harmful emissions are reduced.

Needs of special groups. This multi-functional link task was selected to identify the need for additional tree cover required along Thunder Bay roads in proximity to care homes for people with special needs. It is primarily meant to increase the aesthetics, safety, and cleanliness around care home neighbourhoods and to moderate extreme temperatures, traffic and noise. Similar to children and the elderly, people with special needs (i.e., physically or mentally disabled) are often particularly vulnerable to land-use and transportation infrastructure designs. Until recent support for social equality in cities, many people with special needs had their mobility restricted due to hostile urban conditions. Temperature extremes, excessive traffic noise and pollution, and poorly designed infrastructure frequently restrict the mobility and independence of people with disabilities (Gant 1997).

Since the late 20th century, trees and other green infrastructure have been recognized for their therapeutic effects. Hospitals, geriatric centres, drug rehabilitation centres, care homes for the disabled and prisons have used trees and sensory gardens in healing because of the widespread benefits to patients and prisoners (Maller et al. 2009). Many studies have since reported that patients heal more quickly from physical and psychological trauma when exposed to urban green spaces, and have found that patients have increased motivation for physical exercise and have more social interactions (Gullone 2000; Rappe 2007; Maller et al. 2009). More specifically, Park et al. (2010) have demonstrated that exposure to urban green spaces promotes lower concen-

$$MI = \frac{(SWGI \times w_i) + (SNGI \times w_i) + (STGI \times w_i) + (DCGI \times w_i) + (EDGI \times w_i) + (PPI \times w_i) + (EABGI \times w_i) \times 100}{\sum w_i} \quad (1)$$

trations of cortisol, lower pulse rate, lower blood pressure, and lower sympathetic nerve activity than do non-treed urban areas. Many of these benefits can be realized by greening the immediate premises because views through windows to greenspace throughout the day can be as valuable to patients with restricted access and mobility (Kaplan 1992; Maller et al. 2009).

The restorative benefits of trees also directly and indirectly occur through a decrease in traffic noise and pollution, a reduction in temperature and wind extremes, and a decrease in exposure to UV light. These factors, mitigated by trees, play a significant role in determining if a resident will go outside. They can also help increase the overall well-being of a patient and increase the effectiveness of their therapy.

The maintenance index

This section describes construction of the Maintenance Index within the UFBM. Each of the tasks described earlier identifies areas of priority for urban forest maintenance or protection. The Maintenance Index represents an amalgamation of these priority areas. It identifies sites throughout the city where trees would perform multiple key functions and thus produce higher net benefits, hence the need for maintenance and protection especially in priority areas. The Maintenance Index does not account for present tree canopy cover and tree stocking as this is accounted for in the Planting Index discussed separately below.

The Maintenance Index was compiled using a weighted linear combination approach and is presented as Equation 1 where, *MI* is the Maintenance Index, *SWG* is the stormwater greening task's standardized score, *SNG* is the special needs greening task's standardized score, *STG* is the school travel greening task's standardized score, *DCG* is the downtown core greening task's standardized score, *EDG* is the economic development greening task's standardized score, *PPI* is the priority planting index standardized score, *EABG* is the emerald ash borer greening task's standardized score and w_i is the weight given to each of the seven sub-indices. Values of the Maintenance Index can vary from 0 to 100, where values tending toward 100 have a greater priority for maintenance.

In compiling the Maintenance Index, the contributing task scores (one from each of the seven tasks) were weighted equally rather than placing greater priority (or weight) on one or more tasks. Future research might involve a detailed sensitivity analysis to determine appropriate weighting schemes to explore how alternate weightings of the contributing sub-index scores affect the final Maintenance Index results. Additionally, some users may be inclined to place more weight on specific tasks, for example the standard tasks.

The results of the Maintenance Index for management areas at a resolution of 1 ha are shown in Figure 4. The higher the index score for a given management area, the greater the need to intensify maintenance and protection activities in order to sustain or to enhance the benefits received from tree cover. The index identifies priority locations, regardless of the number of trees or tree canopy percentage in a particular management area. Sections of highest priority identified by the index are the two downtown cores as well as the northwest section of the study area (Figure 4).

The planting index

The Planting Index (PI) is the combination of seven chosen tasks from the Maintenance Index except it accounts for estimates in tree stocking. The spatially optimized services for the Planting Index are represented in Figure 5. The model demonstrated priority areas in both downtown core sections, along with other areas in the northwest and southwest sections of the city.

The tree cover data discussed earlier, and surface cover data provided by the City of Thunder Bay, which demonstrated the spatial extent and distribution of grass cover (soil and other plantable land) in the city, were both used to determine tree stocking, that is, the biologically viable sites to plant trees. The percent tree cover and grass cover were calculated for each 1 ha management area in the study area using the formula of Nowak et al. (2002) and presented as Equation 2. Each variable was standardized on a scale of 0 to 100, with 100 representing management areas with the highest priority for planting (i.e., low tree cover, high grass cover). Generally, areas with low tree stocking levels were identified as areas with greatest priority for tree planting.

$$TS = 1 - \frac{\left[100 - \left(\frac{T}{T+G}\right) * 100\right]}{100} \quad (2)$$

where, *TS* is the tree stocking value (0–1), *T* is percent tree cover, and *G* is percent grass cover.

The tree stocking values, standardized on a scale of 0 to 100 were then subtracted from the Maintenance Index, also standardized on scale of 0 to 100, to provide an estimate of the important areas that are most suited for planting trees (i.e., the Planting Index). The Planting Index, therefore, accounted for the amount of pervious and impervious surfaces in the study area, as well as the extent and distribution of existing tree cover. It demonstrated spatially where trees should preferably be planted to optimize the predetermined benefits and attain desired sustainability goals. The index values range between 0 and 100, with highest values indicating the highest priority for planting (i.e., areas with low tree stocking and a high benefit score attained from the Maintenance Index).

$$PI = MI - TS \quad (3)$$

where *PI* is the Planting Index (0-100), *MI* is the Maintenance Index, *TS* is tree stocking. If TS > MI, then PI=0.

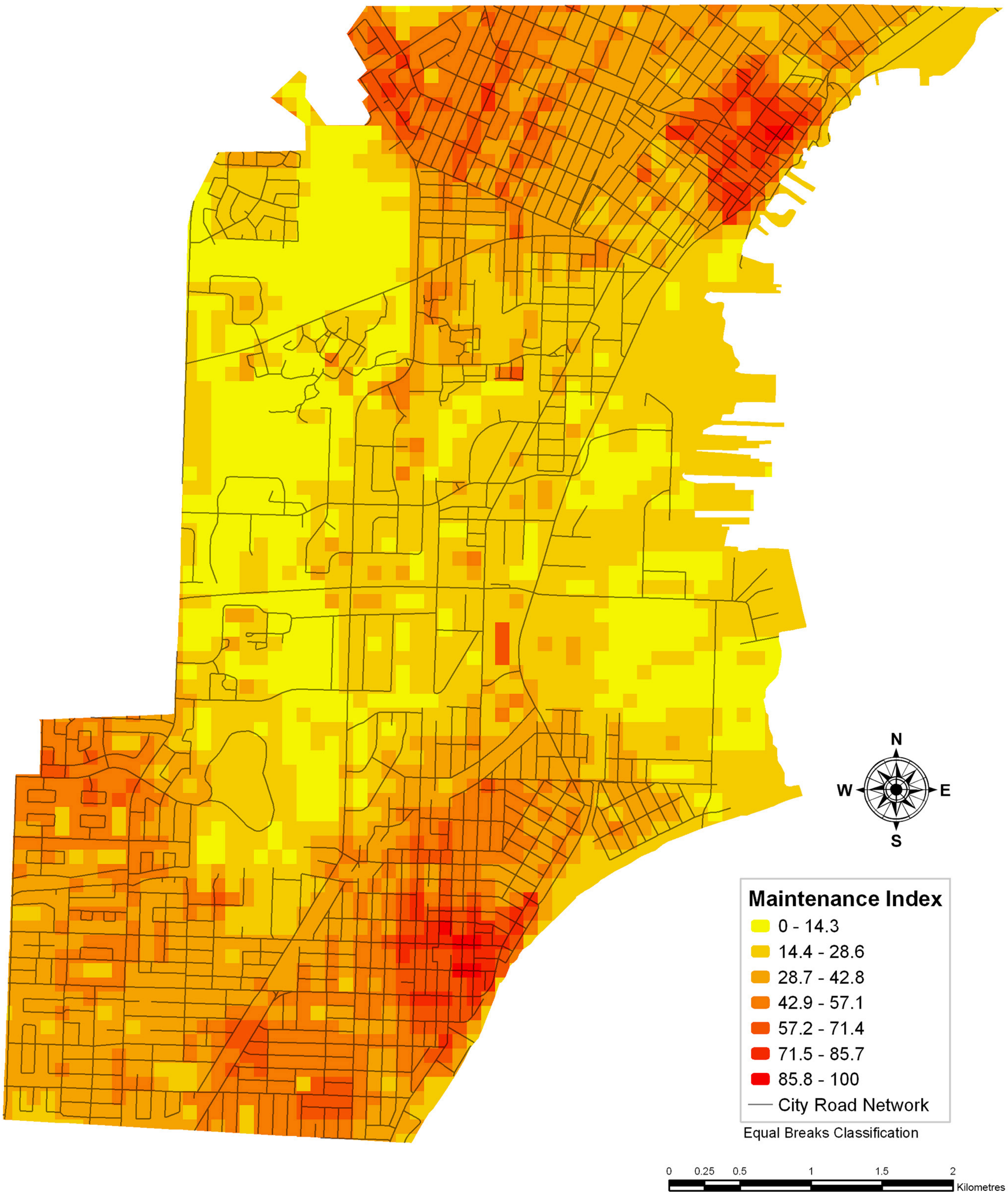

Figure 4
A map displaying the values of the Maintenance Index (MI) for management areas for most of the City of Thunder Bay. Each grid cell represents 1 hectare. Higher values (darker management areas) indicate a need for more focused maintenance and protection.

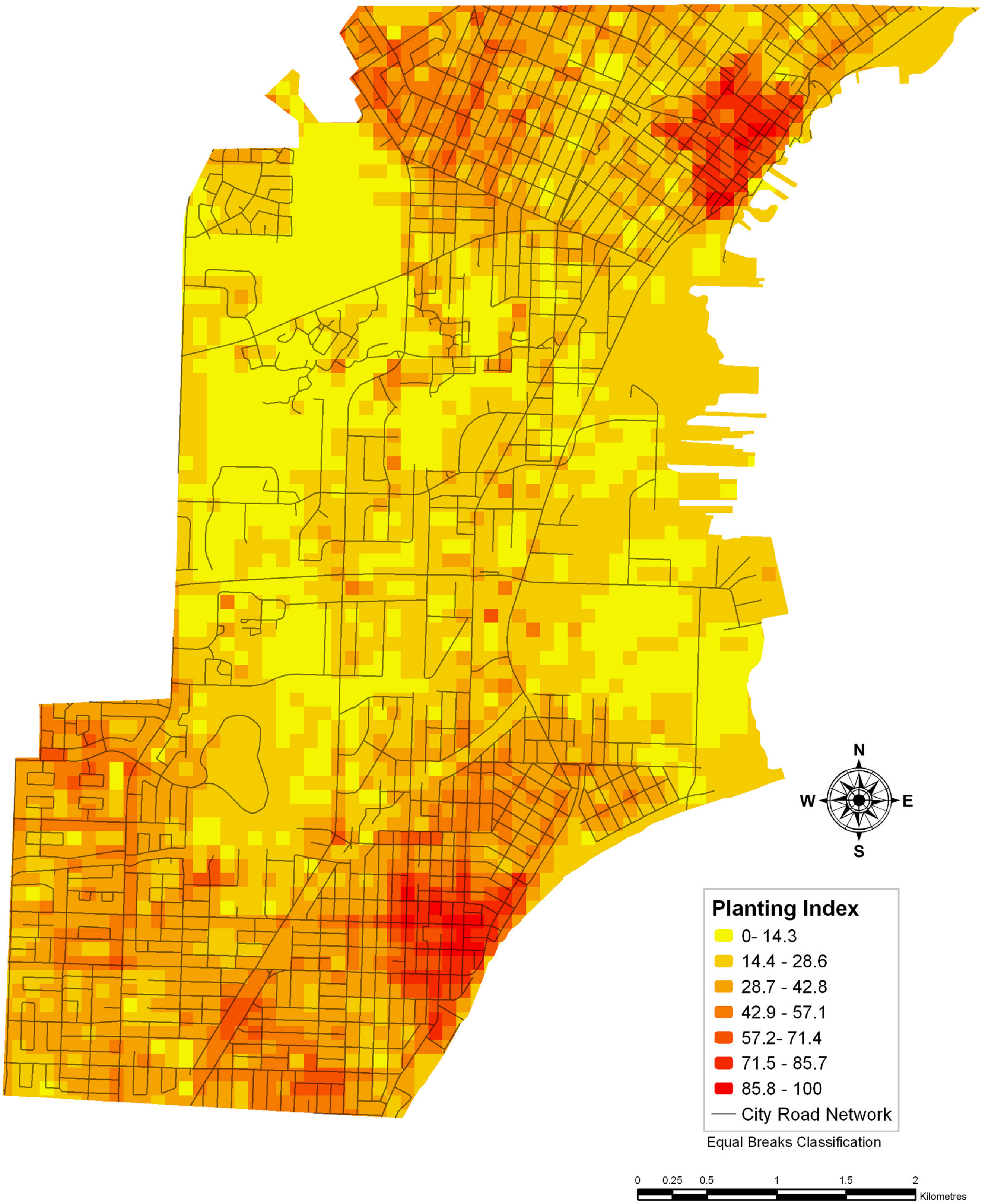

Figure 5
A map displaying the values of the Planting Index (PI) for management areas for most of the City of Thunder Bay. Each grid cell represents 1 hectare. Higher values (darker management areas) indicate a need for more focused tree planting. The management areas in the PI account for current tree stocking values.

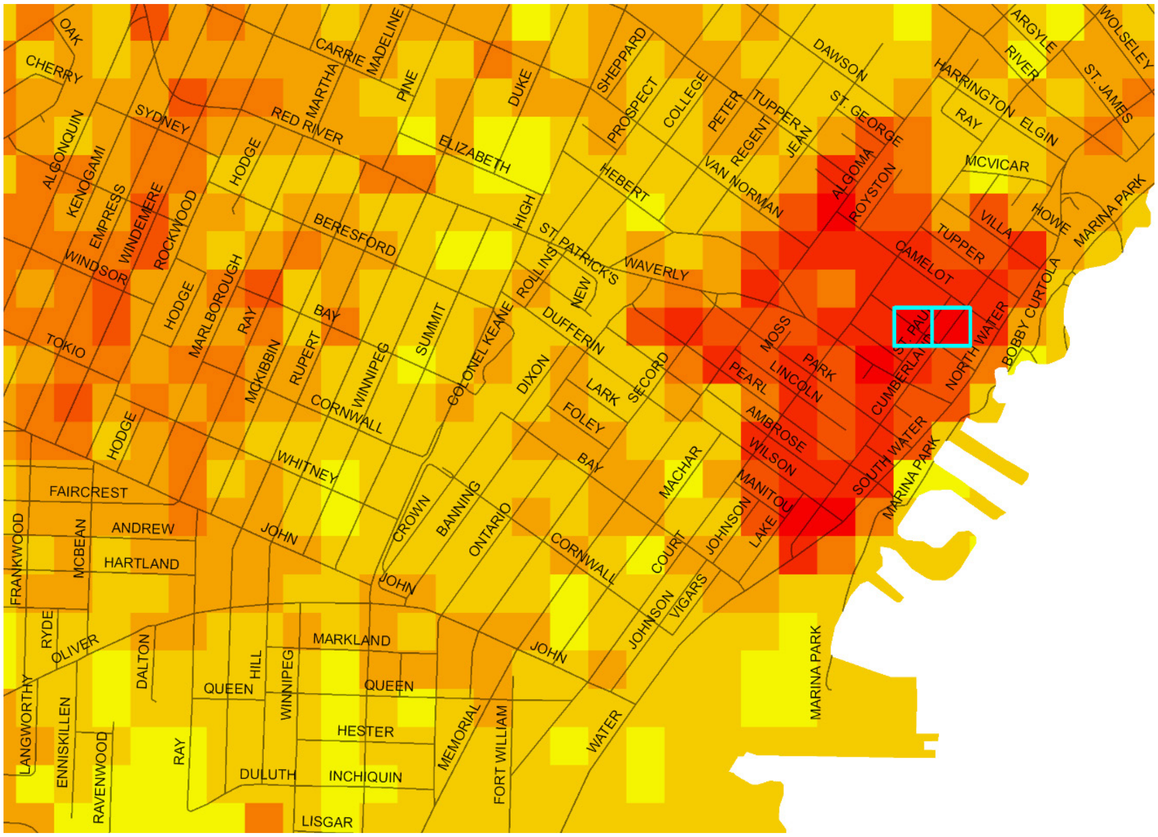

Figure 6
Two of the five management areas across the study area with the highest overall Planting Index values (highlighted in blue) with scores approaching 100. These areas (and other high scoring management areas) command priority for tree planting.

Discussion and conclusion

This article develops a model that spatially optimizes the multifunctional services of green infrastructure in a community. The model is customizable and designed for potential use in other jurisdictions. The medium-scale (i.e., block scale or 100 x 100 m) of modeling within the UFBM and its use of commonly available GIS software to determine planting sites, make it compatible with existing smaller-scale models such as Kirnbauer et al. (2009) and i-Tree™ Design (Hirabayashi et al. 2011) in helping determine planting sites around homes and buildings. However its main purpose is to demonstrate how a municipality might strategize investments in its urban forest to maximize benefits while attaining a variety of sustainability goals. Figure 6 provides an example of how the UFBM output ranks the relative importance of priority planting areas. In this example, two 1-ha pixels are highlighted in the Thunder Bay north core which have Planting Index values approaching 100. Other areas of this older downtown core (darker red shades) are also recommended priority areas for planting (Figure 6). The UFBM developed in this research is the first of its kind to integrate the mitigating, multifunctional goods and services of trees with the tailored sustainability objectives of a community. The model brings together multidisciplinary techniques, and is carried out using interdisciplinary methods.

With resource and budgetary limitations faced by municipalities, the prototype UFBM provides a variety of benefits to communities. Decision makers are now provided with the tools to green their cities in an intelligent, cost-effective manner that maximizes benefits based on the needs of their communities. Urban foresters have the means to modify their existing comprehensive tree planting and maintenance regimes, or create new ones. For example, each city neighbourhood can be ranked based on the average score of its management areas. This ranking exercise provides an output of the neighbourhoods that should have increased frequency of, or increased resources, for pruning. Cities are often subdivided into annual pruning zones, with equal pruning priority assigned to each. Figure 7 demonstrates an example of defining five pruning zones for Thunder Bay based on the average score of its management areas. Zone 5 indicates the highest priority zone that commands more pruning resources and attention to provide a larger return on investment, while zones 1 and 2 have lesser priority due to current city priorities and status of the urban forest and street trees within these areas. This kind of priority-planning approach provides an opportunity to demonstrate new ways of integrating green infrastructure into the urban fabric and could inspire and persuade decision makers to increase funding toward greening initiatives

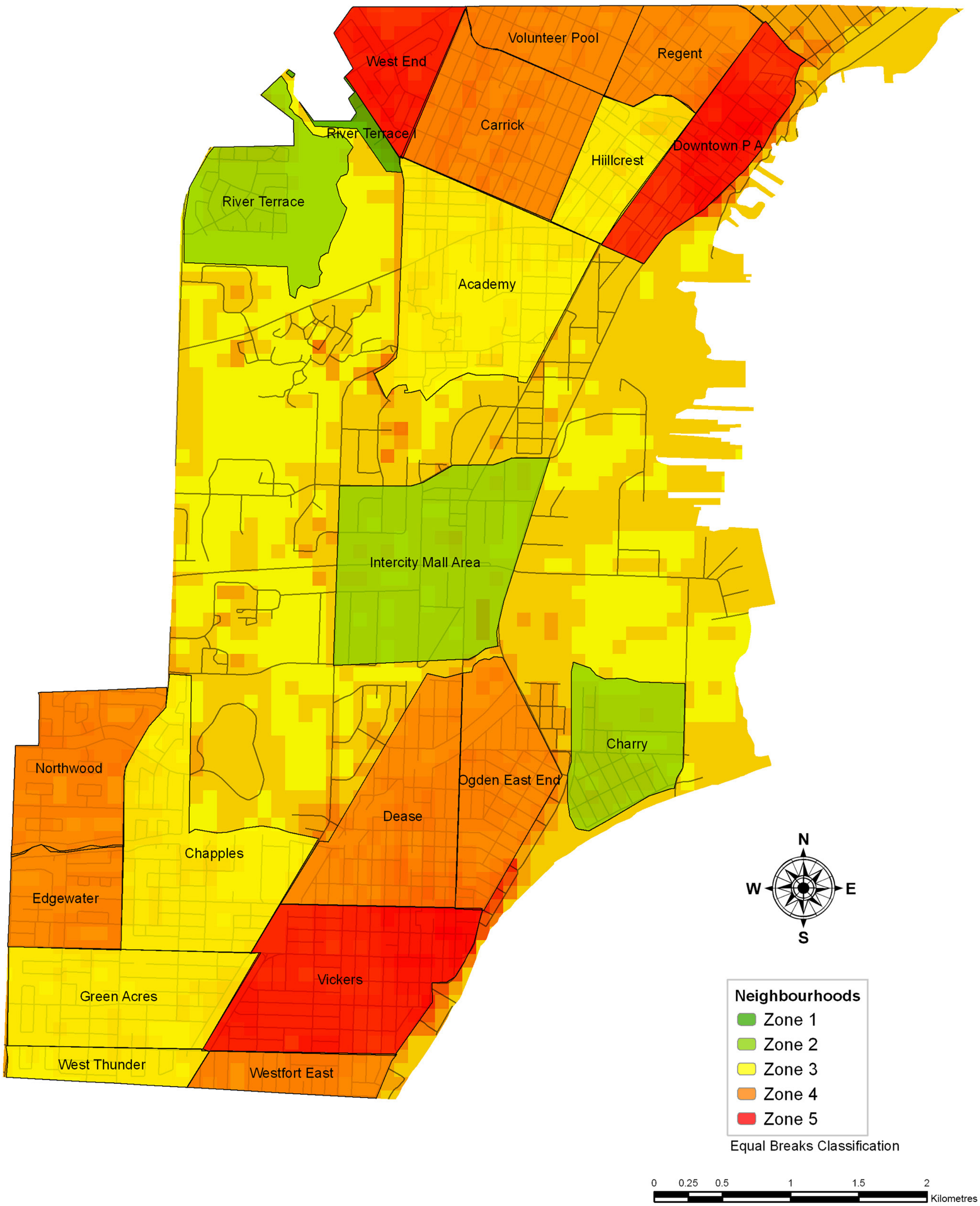

Figure 7
Recommended frequency and resources allocated to pruning across sampled Thunder Bay neighbourhoods. Scores from the UFBM allows decision makers to create pruning cycles based on city-defined priorities and maximizing benefits from the urban forest. High priority zones for more frequent pruning are zones 4 and 5, including Downtown PA, Vickers and West End neighbourhoods.

or provide targeted tax incentives or rebates to homeowners and businesses in high priority areas.

Spatially optimizing urban forest services, as performed in the UFBM, also creates a culture of political and public support by demonstrating visually how an urban forest program contributes toward a municipality's core vision and how it bolsters the mission of other progressive community planning strategies such as Smart Growth and climate change adaptation. The UFBM process requires multidisciplinary coordination and as result can increase buy-in and vital collaboration from other municipal departments and community groups, normally lacking within municipal urban forest programs.

With accurate, visual representations of the urban forests' influence on the goals of the community, the UFBM also creates better training, empowerment and development opportunities for field technicians, and thereby increases the effectiveness and the meaningfulness of fieldwork. Field workers are more informed about enhancing particular key benefits and are able to make better decisions in regards to site design, layout and species selection to facilitate the greatest potential of the targeted UFBM benefit(s).

Lastly, spatially optimized services can be used to inspire decision makers to identify and introduce new approaches to create spaces for trees through brownfield conversions, planting pit developments, and hardscape land conversions, especially in high priority areas.

The benefits-based model provided in this article presents a new comprehensive standard for managing the urban forest and other green infrastructure. The urban forest is highly proficient at benefiting a community's economic, social and environmental capital. This model demonstrates the benefit of shifting the management of green infrastructure to a spatial environment in order to optimize co-benefits according to land use and other program and sustainability goals.

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Prairie Perspectives: Geographical Essays

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An urban park information system using remote sensing and GIS techniques: A case study of Wakamow Valley, Moose Jaw, Saskatchewan

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This research explored the feasibility of remote sensing and GIS techniques to demonstrate their potential for identifying and classifying park/conservation area facilities with special emphasis on the classification of a trail system, and further to develop an information system for efficient management and improvement of park facilities. The study focused on the Wakamow Valley, Moose Jaw, Saskatchewan. Land-cover/land-use information was extracted from high resolution aerial photographs from 2008 and 2014 and classified into bank, grassland, and tree covered areas. A trail system was also extracted from the same images and classified for walkability based on surface type and trail width. Environmental effects, excursions, and recreational activities can cause irreversible damage to park facilities and need to be monitored on a regular basis so that preventive maintenance can be initiated on time. Changes to the trails between 2008 and 2014 were recorded. It was observed that the Moose Jaw River is causing soil erosion along its banks resulting in the collapse of a portion of the Trans Canada Trail. Identification of areas under stress provides important information for effective management of park facilities. This information can be stored digitally using GIS techniques and can help to reduce overall management costs.

Keywords: remote sensing, Saskatchewan, conservation areas, Trans Canada Trail, GIS

Introduction

Increasing interest in outdoor activities and tourism is causing additional pressure on recreational facilities. Thus managers and planners of such facilities are confronted with the difficulty of achieving a balance between preservation, sustainability, and future development of new attractions (Papageorgiou & Brotherton, 1999). The World Tourism Organization (WTO) has emphasized the need for careful planning, management, and continuous monitoring of protected and conservation areas to ensure the long-term sustainability of tourism operations within these areas (World Tourism Organization, 2005). An absence of an efficient and effective information system can contribute to the degradation of these areas and to the reduction of tourist activities (Salerno et al., 2013). An integrated use of remote sensing and GIS technologies can provide a cost-effective solution to this problem and is explored in this study.

Parks and recreation services are an important function of government in all developed nations. Park organizations have

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recently become more involved with the promotion of physical activities leading to healthy lifestyles. Such activities while being a source of leisure and enjoyment, can help to reduce stress and be promoted as preventive measures for stress-related diseases. Involvement in such physical activities requires intrinsic motivation. The process of selecting leisure goals and overcoming constraints to perform an activity depends on personal choices and availability of the desired facilities. If these facilities are properly managed, participants can exhibit an increased commitment to their desired activity (Godbey, Caldwell, Floyd, & Payne, 2005). Ethnic and cultural background can also play a role in the selection of recreational activities. Research indicates that African Americans prefer more open, well designed, structured, and built amenities as opposed to wildland recreation areas (Johnson, Bowker, & Cordell, 2004). Similarly, Canadians are noted for their year round active participation in outdoor activities regardless of weather conditions (CAPS-I, 2017). Thus, an urban park should offer a variety of facilities and amenities including playgrounds, ball fields, and walking trails to cater the needs of a multicultural society like Canada.

Walking is considered an important activity for health, exercise, and relaxation. It can be said that environments which are conducive to walking are conducive to people and provide a variety of benefits, including improved fitness and public health (Litman, 2003). A recent national report "Outdoor Recreation for 21st century America" based on the National Survey on Recreation and Environment (NSRE) as reported by (Cordell, 2008) indicates that 83% of the population participating in the outdoor activities engage in walking for pleasure. Similarly, a Regional Outdoor Recreational Opportunities Study conducted in 2011 by LEES Associates for the demand analysis of Metro Vancouver and Fraser Valley Regional District (FVRD) ranked walking for pleasure among the top five popular outdoor recreational activities. The report further indicated that 92% of the population participated in outdoor recreational activities within Metro Vancouver and FVRD area during 2010-2011 was engaged in walking for pleasure (LEES + Associates, 2011). It is safe to assume that it is one of the most popular outdoor recreational activities. A highly engineered trail system and its regular monitoring and maintenance are required to facilitate hiking in these areas. Trail width and surface type can play a key role in its selection for a particular use. Multiple purpose trails for fast travelers are usually wider to accommodate turns and to reduce the possibility of incidents (Designs Beneficial Inc. et al., 1999). Different surface types including gravel, hardwood, or pavement can be used to prevent or reduce the effects of trail use as these effects can be pronounced causing additional costs for park maintenance. However, some visitors may prefer more natural looking unsurfaced trails. Thus some urban park trails should be unsurfaced or have grass surfaces. For these reasons, an urban park trail system may be a combination of trails having distinctive characteristics. The Universal Trail Assessment Process (UTAP) provides guidance for recording valuable information on these characteristics. This information includes, but is not limited to, trail maps, classification, maintenance records, surface type, width, clearance, user safety, and access. An absence of such information may result in poor management practices. Traditionally, this information is recorded in registers which are difficult to retrieve and update on a regular basis. While GIS techniques provide an efficient tool for inventory management and classification of different facilities within an urban park, remote sensing techniques facilitate their accurate and objective mapping. They can also be used to record temporal changes. These changes may cause a feature to change its class/category, shift its position, expand, shrink, or change its shape and are important to record and monitor for effective management. Technologies like remote sensing and GIS can be used effectively to develop an information system for efficient management of an urban park and conservation area.

This research develops an efficient and effective management/information system for parks and conservation areas using remote sensing and GIS techniques. While any park or conservation area could have been chosen for this study, the Wakamow Valley was selected as it is located in the flood zone of the Moose Jaw River and is in close proximity to the city of Moose Jaw. The city is situated along the river at the intersection of Highway 2 and Trans-Canada Highway in south-central Saskatchewan (Figure 1). It is regional divisional headquarter for Canadian Pacific Rail (CPR) and is an important transportation hub connecting Chicago via rail. Its rich history and relaxing environments made it a choice of history based tourism destination. Because the Wakamow Valley is prone to both ecological stress and human impacts it requires regular monitoring and maintenance. As such, it is ideally suited for this study. Study of the valley offers the additional advantage of generating an information system that can be used by the City of Moose Jaw and the Wakamow Conservation Authority for management and future development of the area.

Methods

A geospatial-based case study, using high resolution aerial photographs of 2008 and 2014, was conducted to extract information on the trail system and its characteristics, and to develop an information system for the Wakamow Valley. The Moose Jaw River, also known as the river of turn while winding through the city, has created a canyon like area close to the south end of the city. This area is prone to spring flooding offering a unique and distinct ecosystem. Wakamow Valley Authority was established in 1981 by provincial act and the valley was declared as a conservation area. It is also a four-season urban park with over 20 km of trails, three playgrounds, seven park pavilion areas, and about 200 hectares of parkland and natural habitat (Tourism Saskatchewan, 2016). As the study area (Figure 1) is an urban park in close proximity to a tourist city, it has a high visitation rate and thus requires regular monitoring and maintenance.

High-resolution aerial photographs acquired in 2014 were used to extract land-use and land-cover information and to develop a map of the study area. Traditionally, there are different techniques and approaches cited in the literature that have been used successfully to integrate spatial information from various sources into a single GIS platform. However, remotely sensed

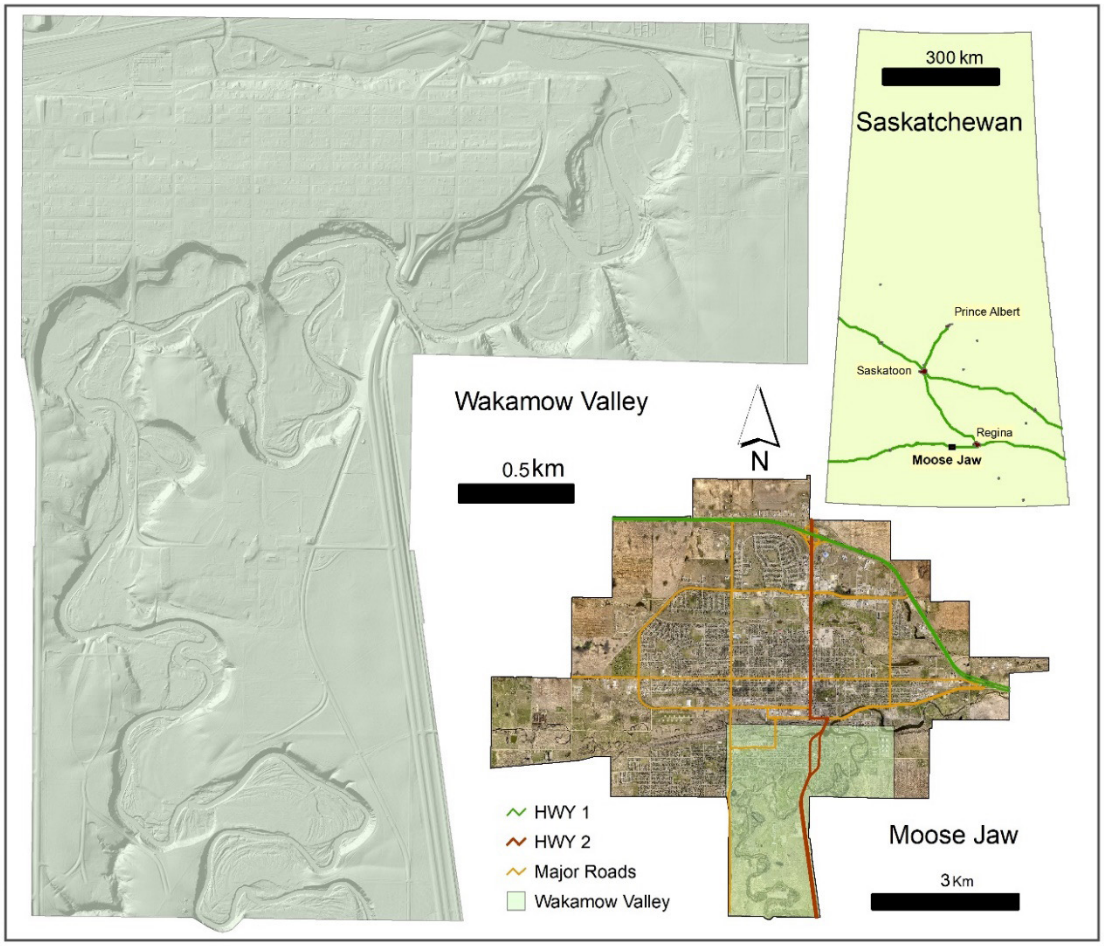

Figure 1
Project area

data is playing an increasingly significant role in GIS applications. This data needs to be georeferenced to a common local coordinate system so that extracted features can successfully be integrated into the GIS system. High resolution aerial photographs of 2008 and 2014 were used for temporal analysis to record changes over the period of six years. The flowchart shown in Figure 2 summarizes the methodology segments used in this study.

High resolution (10 cm spatial resolution) aerial photographs of 2008 and 2014 were georeferenced as the first step. For this procedure, a set of several well-defined and accurate ground control points (GCPs) were collected through a handheld Trimble 6000 Series GeoXH GPS device. The accuracy of the georeferencing process depends on the number, distribution, quality, and precision of the GCPs (Gao & Zha, 2006). A standard method of collecting GPS values in a relatively open area for up to 15 minutes and post-processing differential corrections were applied to improve the measurement accuracy of the GCPs. As recommended by Toutin and Chenier (2004), 38 well-distributed GCPs along with their RMS error was calculated. Sub-pixel georeferencing accuracy required for accurate temporal analysis and change detection was achieved by rejecting GCPs with higher RMS error and used only the most accurate GCPs (Smith & Atkinson, 2001).

After georeferencing, image enhancement techniques were applied to these images to improve feature identification and extraction. It was observed that the 'percentage clip' worked best for these images. Research suggests that an onscreen/heads-up digitization is a viable and proven method for feature extraction from high-resolution remote sensing images (Marion (Marion, Leung, & Nepal, 2006). This technique was used to extract land-cover/land-use features including the trail system, tree canopy, grassland, and water bodies. These feature classes were converted into vector layers for their efficient integration into a GIS system. The information collected from the detailed ground surveys was added to the attribute table of these vector layers. Some of the ancillary information obtained from the City of Moose Jaw and Wakamow Valley Authority was also incorporated into the attribute tables in order to build a comprehensive inventory management and information system. Integration into the GIS-based attribute tables provided a base for spatial analysis and accurate mapping of the study area.High resolu-

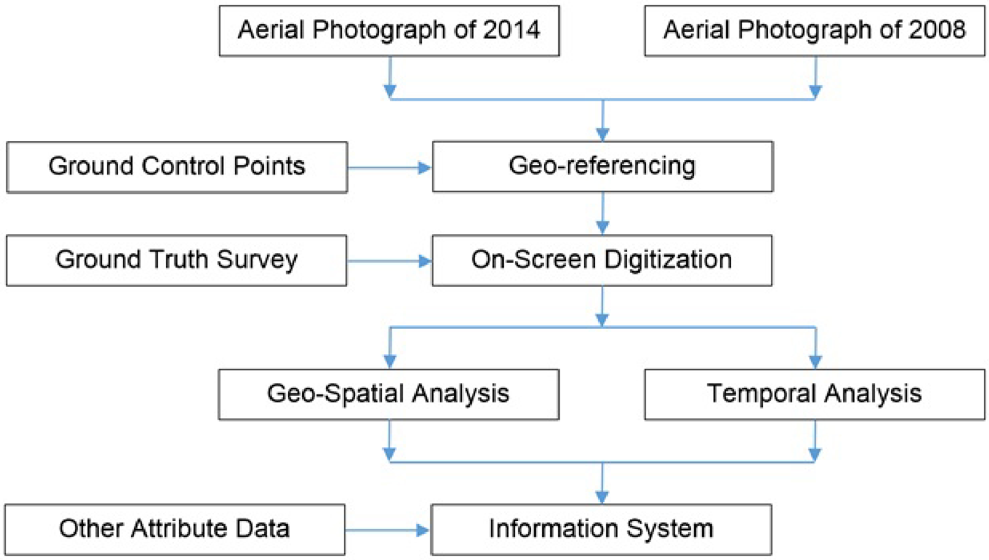

Figure 2
A flowchart explaining methodology

tion aerial photographs for 2008 and 2014 were used to record the changes over the six-year periods. Various digital methods have been reported in the literature, but an interpreter analysis of high-resolution aerial photography can produce accurate results with a great degree of precision as compared with the automated analysis techniques (Coppin, Jonckheere, Nackaerts, Muys, & Lambin, 2004; Edwards, 1990). Several changes were detected during this process. However, some of these changes were not recorded as they had minimal effect on the daily activities of the park. Thus, a decision was made to record only areas prone to soil erosion causing a significant threat to the trail system.

Results and Discussion

As a result of the on-screen digitization of the aerial photograph of 2014, a total of seven feature classes comprising trail system, grassed land, tree covered area, non-vegetated (bank) area, water bodies, road network, and building footprints were extracted. A summary of the vector layers for land-use/land-cover classes along with their measurements is given in Table 1.

Ancillary information obtained from other resources and ground truth surveys was added to these layers as attribute tables to create different layers for a GIS system and to develop a base map of the area. Classification of trails by a) surface type and b) width and associated land cover is shown in Figure 3.

Detailed spatial analysis of the study area shows that 53.5% is in grassland, 39.7% is covered by trees, and 6.8% is the non-vegetated area along the banks of the Moose Jaw River. Trails in the study area have a combined length of 20.1 km. The majority of trails (80%) have either a grass or gravel surface requiring regular maintenance (Figure 3a). Their respective contribution to the trail system is 45% and 35%. Only 20% trails have hard surfaces that can be used in all weathers and seasons. Whereas the widths of trails vary from 1 to 2.5 m, 59% of the trail system is 2 m wide (Figure 3b). The narrowest trails are 1 m wide. They

Table 1
Land-cover/land-use classes and their measurements

Attribute Name	Type	Area or Length			Percentage (%)
River bank	Polygon	352,518.39 m^2	~	0.4 km^2	6.8
Grass land	Polygon	2,785,709.19 m^2	~	2.8 km^2	53.5
Tree covered	Polygon	2,066,206.94 m^2	~	2.1 km^2	39.7
Total Area	Polygon	5,204,434.52 m^2	~	5.2 km^2	100.0
Trails	Polyline	20,105.97 m	~	20.1 km	

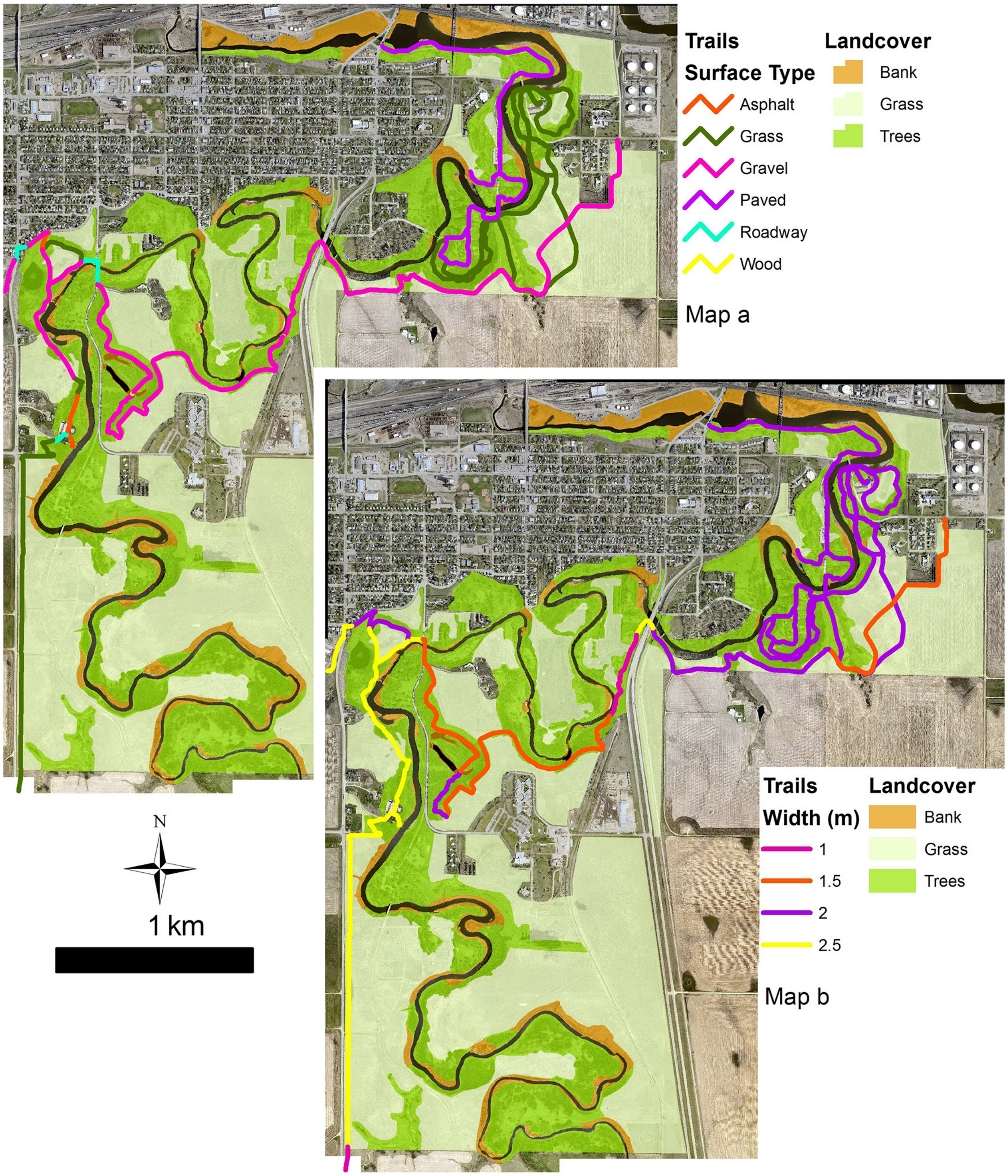

Figure 3
A set of maps where vegetation land cover overlaid by trails: a) classified by surface type and b) by width

are usually the shortest in the system and constitute only 3% of all trails. Trails with widths of 1.5 m and 2.5 m each contribute 19% of the trail system.

The Moose Jaw River winds through the Wakamow Valley causing soil erosion along its banks. This erosion has become prominent in certain parts of the valley (Figure 4). Remote sensing images reveal that between 2008 and 2014 an estimated area of 996 m^2 was affected by erosion, and caused about 68 m of the Trans Canada Trail to collapse into the river. This portion of the Trans Canada Trail was redesigned and requires special attention to stop further erosion. Similarly, Moose Jaw River is also causing significant erosion in the close vicinity of some other portions of the trail system as it is prominent in the upper right corner of figure 4. Despite of the fact that this portion of the trail system is under a serious threat of collapsing posing danger to its users, it has yet not been redesigned. Preventive maintenance through reinforcement of river bank and regular monitoring of the area is required to avoid costly redesigning of the trail system.

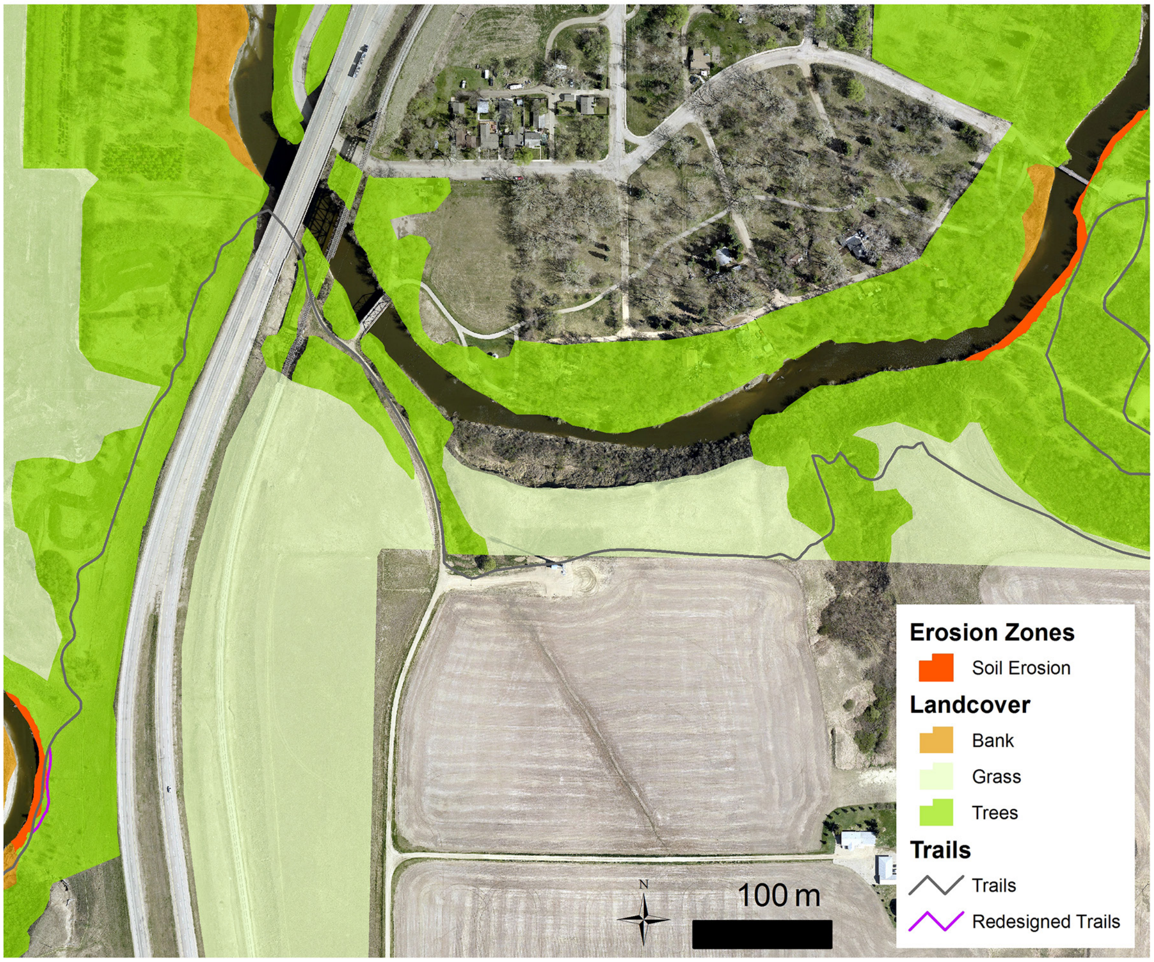

Figure 4
Soil erosion and trail redesign along the Trans Canada Trail, Wakamow Valley Park

Conclusion

Parks and conservation area management requires frequent information on a timely basis about the resources, physical characteristics, and visitor impacts on any given area. This information is helpful for preventive maintenance so facility degradation caused by its excessive use or by natural phenomena, such as flooding or soil erosion, can be addressed on time to avoid further damage. Receipt of timely information can also play an important role in the efficient management of existing facilities and the introduction of new amenities. Limitations in staff and funding frequently constrain conservation authorities in obtaining such information. This difficulty can be reduced through the use of remote sensing and GIS techniques to develop a comprehensive information system. It is concluded that high-resolution satellite images or aerial photographs can be used effectively to extract land-cover/land-use features. In the current study, changes happening over a period of time were recorded through a temporal analysis using images of the Wakamow Valley acquired for 2008 and 2014. This analysis proved helpful in identifying areas under stress which need regular monitoring. Ancillary information attached with the land-use/land-cover classes extracted from the aerial photographs may prove useful for preventive maintenance and future development of the area.

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Prairie Perspectives: Geographical Essays

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Subsurface erosion features in badlands revealed by high resolution digital evaluation models

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The use of small unmanned aerial vehicles (UAVs) to collect high resolution orthophotography to analyze drainage connectivity was evaluated based on field studies conducted in partnership with the Spatial Information Management and Modeling Unit, Saskatchewan Ministry of Environment. Photographs were taken with a consumer-grade UAV with an integrated gimbal-mounted digital camera and structure-from-motion (SfM) image processing software to reduce the data gap scale and satellite scale. SfM is a low-cost and photogrammetric technique which was used to create high-resolution digital elevation models (DEMs) from photosets.

DEMs were used for quantifying different badland surfaces and for detailed recognition of geomorphic features related to erosion and accumulation. Results suggest that decimeter-scale accuracy can be achieved using SfM in areas with complex topography such as badlands. The altimetry reconstitution of different badland surfaces and drainages features were applied to calculated potential surface and subsurface erosion. Stream power index (SPI) was calculated for the original DEM and the pre-processed depressionless DEM. Filling sinks removed depressions within the flow accumulation dataset and created a drainage network including the subsurface pipe network similar to reality.

Keywords: badland, SPI, UAV, drainage connectivity, subsurface erosion

Introduction

Complete knowledge of soil erosion processes is still lacking due to the inadequacy of current data in detecting the spatial and temporal variables associated with surface, and especially subsurface, erosion. Difficulties exist in the recognition, description, and quantification of soil erosion due in part to limited information on the magnitude and frequency of events that cause erosion and in part to the lack of cheap and reliable methods of erosion assessment (Boardman 2006). However, low-cost unmanned aerial systems (UASs) and photogrammetry software have enabled researchers to generate more accurate digital elevation models (DEMs) to monitor erosion at different temporal and spatial scales (Watts et al. 2012; Fonstad et al. 2013). Research reported here shows that UAVs can also capture partly invisible, subsurface processes.

The Avonlea Badlands is a typical badland characterized by high erosion rates, involving overland flow and pipe flow as the dominant processes (Figure 1) (Bryan and Yair 1982; Campbell 1989; Faulkner et al. 2008). While it is known that badland morphology is often the result of surface and subsurface erosion and sedimentation processes, there is a lack of research about subsurface erosion compared to that of surface processes. The reasons are that they are less visible and more difficult to investigate (Campbell 1989; Faulkner 2013).

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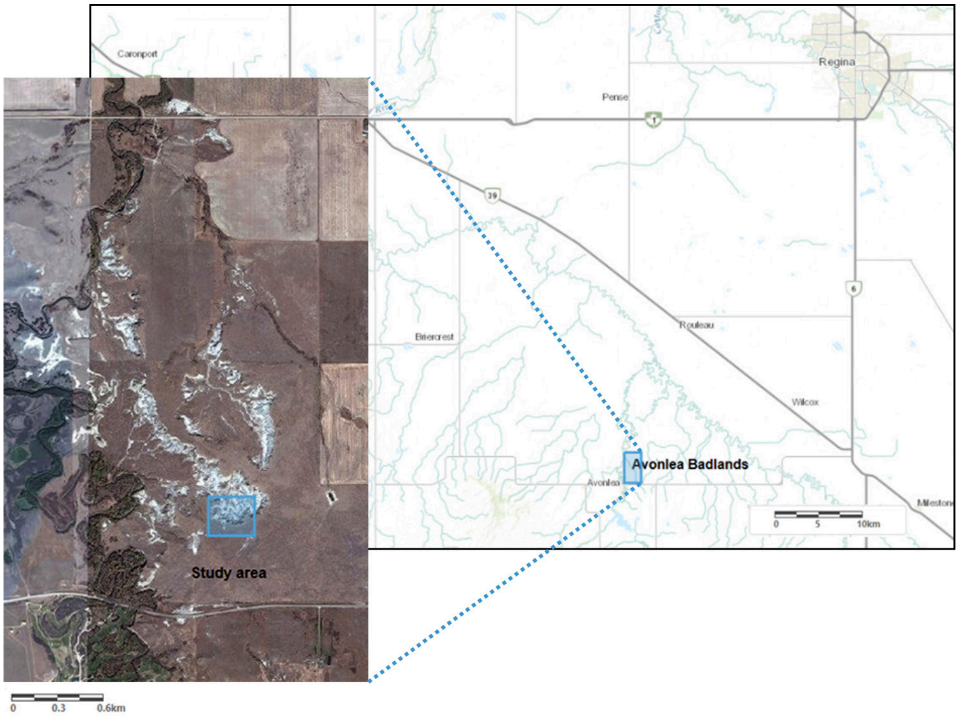

Figure 1
Location of study area

Aerial photographs taken by drones are useful tools for measuring and monitoring changes caused by erosion in a fast changing, heavily dissected badland landscape, as traditionally obtained photographs and DEMs are generally too coarse to provide sufficient detail. The available orthophotography of the study area collected by the Saskatchewan Government Imagery Collaborative has an approximate 60 cm pixel spatial resolution and the most commonly used DEM at a provincial level has a spatial resolution of 10 m (Figure 2).

The use of unmanned aerial vehicles (UAVs) to collect high resolution photography was evaluated based on field studies conducted in partnership with the Spatial Information Management and Modeling Unit, Saskatchewan Ministry of Environment. A high-resolution topographic model was created to identify different badland surfaces and for detailed recognition of geomorphic features related to erosion and accumulation in the heavily dissected badlands landscape.

Limits of this technology in mapping and altimetry reconstitution (DEM) of badland surfaces and drainages features were evaluated. DEMs were used to identify areas of surface and subsurface erosion in the landscape using the terrain attributes of slope, flow accumulation, and stream power index (SPI) (Galzki et al. 2011).

This study assesses the effects the original DEM and the preprocessed depressionless DEM have on SPI and what each reveals about the erosion potential in the study area. The method of using terrain attribute calculations to identify areas of accumulated runoff was applied and evaluated for its effectiveness in identifying potential areas of high surface and subsurface erosion by water in the Avonlea Badlands of Saskatchewan, Canada.

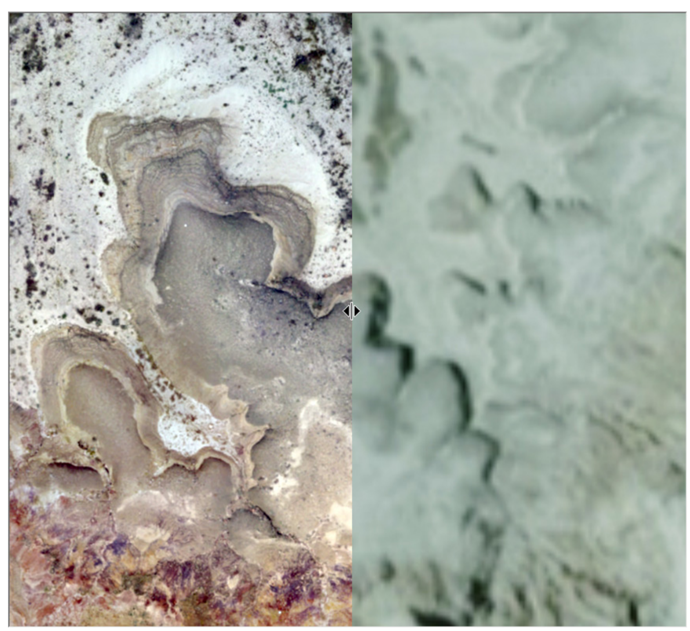

Figure 2
Split screen view of the UAV acquired imagery compared to the best available orthoimage for the study area

Study area

The study site of the Avonlea Badlands is located along Avonlea Creek, 60 km southwest of Regina, Saskatchewan (Figure 1). The climate is semi-arid continental with wide variations in seasonal temperatures characterized by cold winter and hot summer months. The mean annual precipitation is 390 mm (Regina International Airport 1981–2010), of which about 30% typically falls as snow (Environment Canada 2017). The Avonlea Badlands are cut into the Eastend Formation. The development of the badland was triggered by rapid post-Pleistocene incision of a meltwater channel in the marine and lagoonal sediments of the Upper Cretaceous (Christiansen 1961; Kent and Vigrass 1973). The Canadian prairies provide a natural setting for the evolution of badlands, especially where Cretaceous formations consisting of highly active clay minerals such as the various members of the smectite group are exposed (Bryan et al. 1984).

The Eastend Formation consists of an upper unit generally with thick-bedded sandy strata forming a steep slope and a lower unit with a thin-bedded muddy strata capped by a bentonitic layer. Bentonite contains swelling clay minerals which can absorb up to several times their weight in water. After drying, the bentonite shrinks and forms a typical popcorn surface with cracks. Most of these cracks and fissures close during wetting due to swelling and create nearly impermeable and relatively resistant surfaces (Bluemle 1996) (Figure 3). Sandstones are composed primarily of quartz and calcite sand grains with resistant concretionary ironstone fragments. Slope drainage of steep sandstone and the upper mudrock is often routed through deep pipe networks (Kent and Vigrass 1973). Piping or tunnel erosion is described as a natural erosion process by which infiltrating water forms tubular subsurface drainage channels (Dunne 1990; Wilson 2011). The first visual signs are little sinkholes built up by subsurface erosion in the upper mudrock. Sometimes collapses of pipe roofs take place in segments resulting in a line of holes and gullies on the surface (Bryan and Yair 1982; Campbell 1989).

Seven badland surfaces can be identified. First, a vegetated stabilized uppermost prairie surface with short grass vegetation overlays a second upper steep slope surface of mud cemented sandstone (Figure 3a) with slope of 80° to 85°. The sandstone layer includes cross-bedded arkoses and muddy sandstones with thin shale or silt partly but densely rilled and piped (Figure 3b). Sandstone surfaces have a very thin weathering rind, frequently

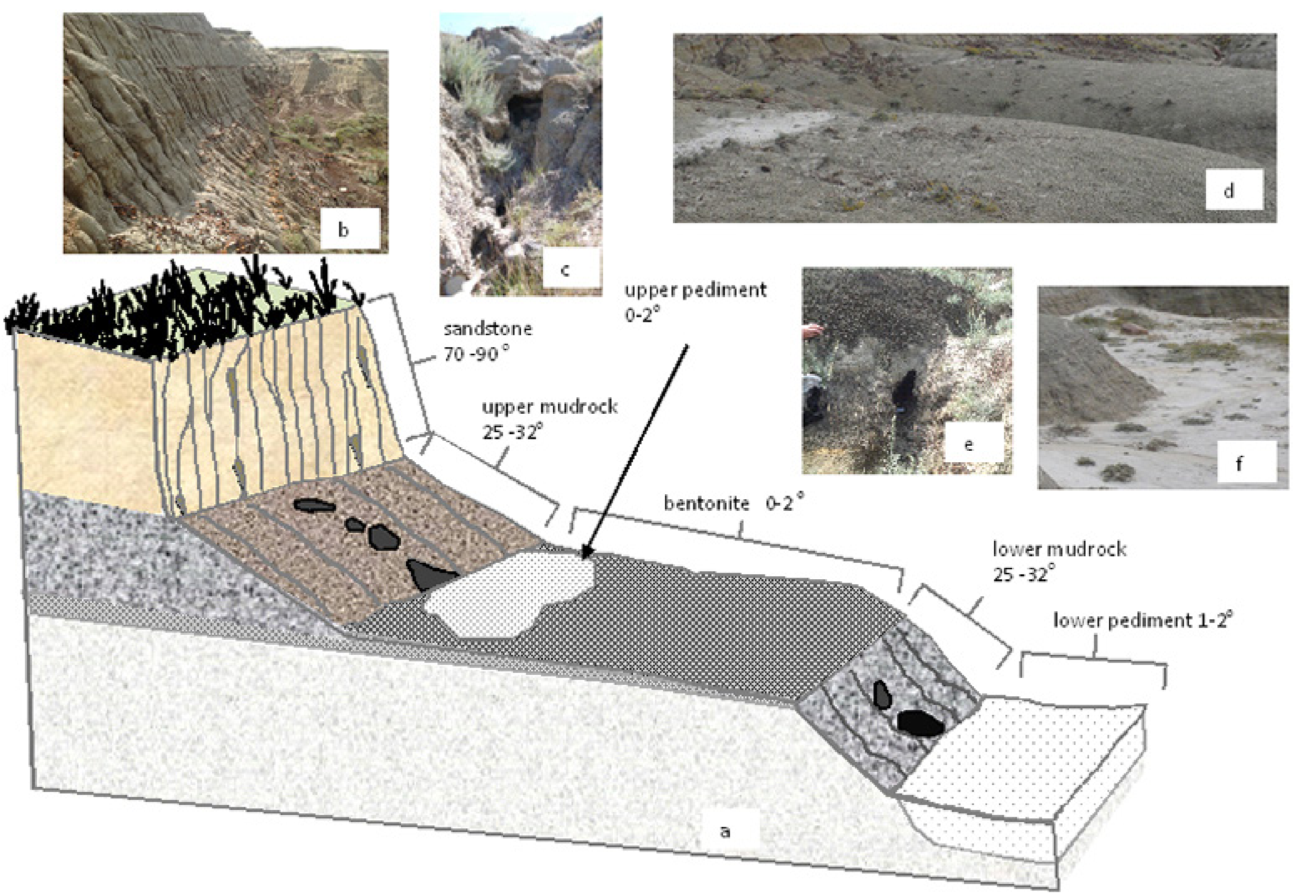

Figure 3
3a Typical slope profile of the study area. 3b steep sandstone slope with rills. 3c upper mudrock slope with pipes shaft and collapsed pipes,. 3d bentonite slope partly covered by upper pediment. 3e lower mudrock with pipe shaft, 3f lower pediment.

pitted due to raindrop impacts (Kent and Vigrass 1973). A third surface is developed in mudrock in the upper mid slope with a slope angle of 20° to 2°. This slope segment is characterized by a veneer of ironstone shards and collapsed pipes (30–60 cm diameter), and pipe shafts, tunnels and gullies (Figure 3c). In the study area most pipes follow the hydraulic gradient modified by lithological variations. Glacial tectonic joints, tension cracks, and desiccation cracks function as preferential flow paths.

The transition from the upper mudrock to the level bentonite surface is marked by an upper > 30 cm thick pediment covering parts the bentonite surface and forms the fourth surface. The fifth surface is a nearly level mid slope segment formed by a bentonitic mudstone with a typical popcorn surface and slope degree of -2° to 2° (Figure 3d). A sharp break between the lower mudrock slope (Figure 3e), the sixth surface, with a slope degree of 26° to 34° leads to the lower pediment, the seventh surface. The pediments are easily recognizable in the landscape because of their lighter colour (Figure 3f).

Material and methods

A small UAV, a DJI Phantom 2 Vision + Quadcopter, carrying a 14 megapixel (FC200) gimbaled camera was used to acquire detailed aerial photographs of the study area. Flights followed waypoint controlled transects at a spacing estimated to provide good overlap (approximately 80%) for orthophotography. Photographs were set to be taken every three seconds during the flight. The mission was completed at 30 m above the prairie level. Photography was processed using Agisoft Photoscan Professional© (2014), an image-based 3D modeling program in which overlapping images are aligned and calibrated using common points found in the photographs. Further processing can be used to produce a terrain model and geometrically correct orthomosaic.

UAV-based photogrammetry was processed to create a dense point cloud and DEMs along with measured ground control points (GCPs). Fourteen GCPs were installed prior to the survey throughout the study area using a 15 cm metal survey spike set with the top of the spike head level with the surface and an air photography target was centred over the spike at each locate (Figure 4). The GCPs were measured at the centre of the target using a Trimble Geo7x global navigation satellite system with centimeter accuracy real time kinematic positioning enabled. The GCPs were used in post processing of the imagery for improved imagery and model placement. The three-dimensional position (X, Y, and Z) differential correction resulted in corrected positions of all GCPs being in the 0 to 5cm range.

The accuracy of DEMs generated from UAV imagery light detection and ranging (LiDAR) is highly dependent on good ground control point placements and their measurements. Santise et al. (2014) modeled DEMs for several scenarios including over 3500 GCPs for an area of approximately 500 x 500 m and found that as few as nine carefully placed GCFs in an area of similar size to the current study area was sufficient. UAV obtained DEMs perform competitively in comparison to traditional LiDAR-based imagery for overland flow modeling, but offer the advantage of being easier to obtain more frequent and more affordable updates (Leitão et al. 2016).

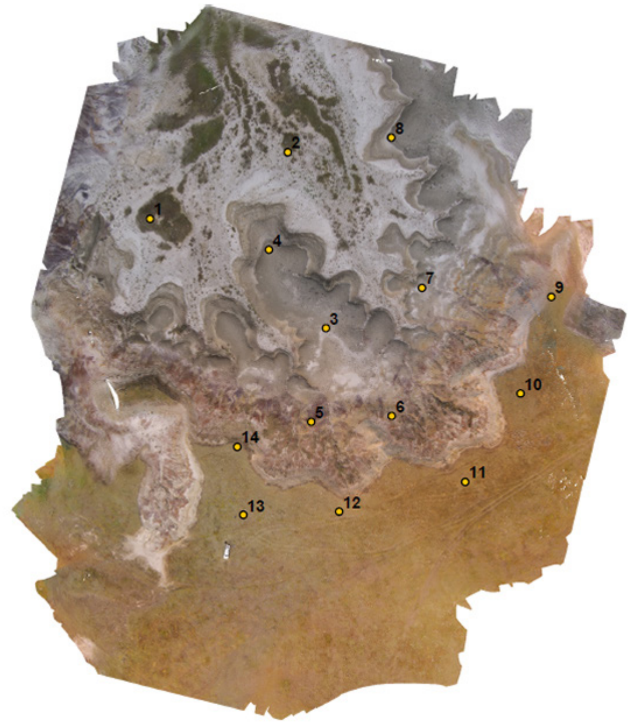

Figure 4
Location of the GCPs in the study area

Data processing

Multiview stereo was implemented by using the Agisoft PhotoScan (Agisoft LLC. 2014) to produce a dense point cloud using pixels of the supplied photographs. The data were used to generate a high resolution DEM with 0.4 m grid cell resolution. After calculating the primary attributes (aspect, slope, and flow accumulation) directly from elevation data, the Stream Power Index (SPI) as secondary attribute was calculated from the primary attributes using tools found in ArcGIS (Figure 4). Percent-based slope was calculated as rise divided by run multiplied by 100, and was used directly in the calculation of SPI.

The SPI is a measure of the erosive power of water flow. It is also the potential energy available to carry sediment (Moore et al. 1993; Conforti et al. 2011). In order to calculate the SPI, a flow accumulation raster from the digital elevation model was created. Flow accumulation into each cell is the count of all cells that flow into a downslope cell. SPI was calculated for both DEMs, the original DEM and the preprocessed depressionless DEM, using the Raster Calculator tool with the equation SPI = ln ((flow accumulation + 0.001) * ((slope / 100) + 0.001)). The z-limit is the difference between the depth of the pit and pour point. Slope, percent rise, flow direction, and flow accumulation were calculated for both DEMs. SPI was calculated for both DEMs using the Raster Calculator tool with the equation SPI (University of Minnesota 2012) (Figure 5). The addition of the 0.001 in the above equation helps to prevent 0 values. Thus, classifying flow accumulation with different cut-off values can help to better visualize the drainage network and identify areas which have the highest potential for surface erosion. After comparison with the field survey a cut-off point at 500 was chosen for both DEMs. A cut-off above 500 showed approximate locations where flow lines might be more likely to form on the landscape and contribute to the drainage network.

The flow accumulation raster creation has the option to either fill or not fill depressions. Often these depressions are considered processing artifacts within the DEM due the resolution of the data or rounding of elevations to the nearest integer value (Arnold 2010). A DEM was produced by applying fill without specifying a z-limit (elevation) value (Figure 5d).

Results

The flow accumulations of both the depression-filled and non-filled DEMs was compared with the aerial image of the badlands and with a detailed geomorphic field map of the study area (Figure 5). The lowest SPI corresponds with the location of the bentonite surface, the prairie level and the pediments with level or very gentle slope. The highest SPI corresponds with the upper and lower mudrock slope.

The unfilled DEM SPI results show no connection between the different badland surfaces, indicating a unconnected surface slope drainage system (Figure 5c). In particular, the drainage system of the upper mudrock seems to be isolated from the drainage systems downslope because of a complex pipe and gully network developed in the sandstone and upper mudrock slope segments.

The field map (Figure 5a) shows many pipe shafts in the lower part of the upper mudrock slope, and small discontinuous gullies developed by collapse of pipe roofs (Figures 3c and 3e). The upslope sandstone and upper mudrock surfaces with flow lines converging to the pipe shafts and gully positions suggests a connection of the surface and subsurface drainage systems. While the first stages of piping erosion are invisible on the surface, with the pipe roof collapse the subsurface erosion is clearly visible. Pipe enlargement continues through removal of material during heavy rains, causing sections of pipe roof to collapse, creating a linear sequence of small discontinuous gullies (Figure 3c). These pipes greatly increase the movement of water down the slope when discrete sections of pipe begin to form and subsequently link up, building a continuous pipe parallel to the surface. The increase in the rate of both surface and subsurface flow enables widening and expansion of the pipes. At this stage, the development of piping erosion may significantly alter the hydrological and geomorphic slope systems. Hydrologically, pipes can act as an effective drainage system, with pipe networks enhancing drainage. The presence of pipes often increases the peak flow during storm and shortens the response time (Anderson and Burt 1990; Dunne 1990).

There is a spatial association between pipe shafts and narrow gullies and surface flow lines in the study area. Because of their size (diameter 30 to 80 cm) they were not detected as a single feature, but rather as a larger depression which leads to the termination of the flow during calculation of the SPI without depression fill DEM. For the study area, these breaks in the non-filled flow accumulation indicate the location of pipes combined with small gully systems (Figure 5b). SPI, without depression fill, detected areas where subsurface erosion features such as pipes and small gullies were mapped and correctly identified as depressions which leads to the termination of flow lines (Figure 5 c). The depression-filled DEM SPI connected the surface and the subsurface drainage system and created a realistic representation of the drainage network when compared to the field survey (Figure 5a and 5d).

Discussion

Surface runoff simulations using the depression-filled and non-filled DEMs differ substantially due to the typical hydrologic characteristics of badlands, where surface and subsurface flows occurs. For the study area, the application of high resolution DEM and geographic information system (GIS) technologies for assessing erosion, including the calculation of the terrain factors that control erosion, will be incomplete without including subsurface erosion. Subsurface erosion processes like piping are often a neglected process in badlands erosion studies because they are mostly invisible and difficult to research (Faulkner 2013).

The field survey (Figure 5a) documents a series of shafts associated with small gullies located on the lower slope of the upper mudrock at the end of surface flow lines. The topographic distribution of pipe-roof-collapse features (Figure 5a) suggests that the subsurface drainage system is connected to the surface drainage system in the study area. For the SPI calculated for the unfilled DEM (Figure 5c) flow lines end at the locations where pipes and small gullies were mapped. The drainage network of the upper slope, consisting of sandstone and upper mudrock, and the lower slope, consisting of bentonite, lower mudrock and lower pediment, are disconnected. The SPI calculated for the depressionless DEM (Figure 5d) shows a drainage network similar to the field survey (Figure 5a).

Depression-filled flow accumulation is generally considered to be a more accurate representation of the surface drainage network because depressions would fill with water and then overflow (Arnold 2010). However, in areas with subsurface erosion such as karst and badland environments they can document the location of sinkholes and collapsed pipes (Arnold 2010; Jacoby et al. 2011). Since the study area consists of badlands with a subsurface drainage networks, depressions or sinks are likely and it cannot be assumed that all depressions are errors. By filling the depressions of the DEM, surface and subsurface drainage marked by sinkholes and collapsed pipes were connected. By removing the depressions a drainage network connecting the surface and subsurface drainage networks was created, resulting in greater water accumulation downslope, and reflecting a more

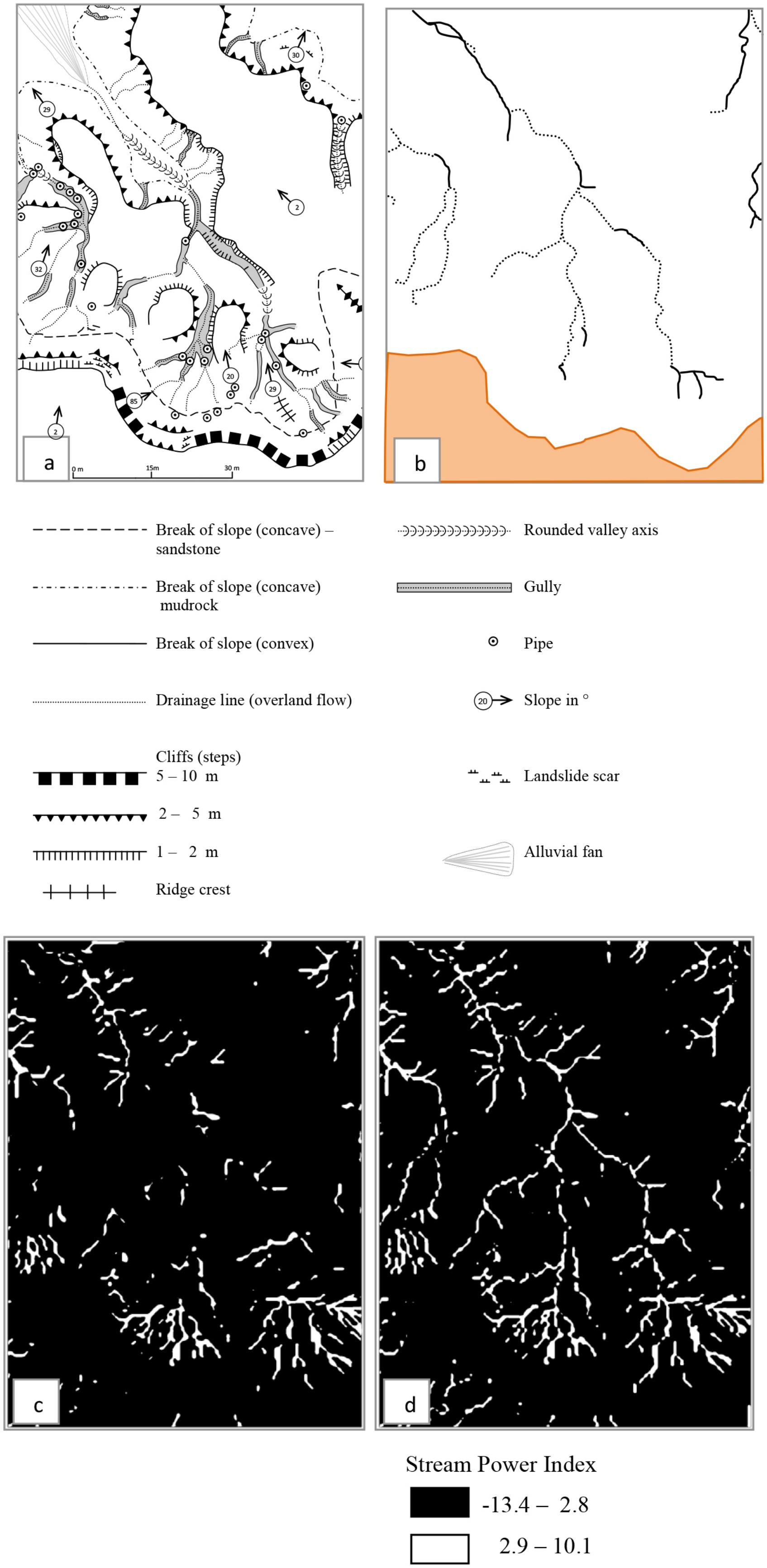

Figure 5
5a Geomorphic map of the study area. 5b Flow accumulations of both the depression-filled (dotted line) and non-filled DEMs (solid line). 5c SPI of the non-filled DEM. 5d SPI of the depression-filled DEM.

realistic erosion potential of the drainage network consisting of surface and subsurface parts. The results indicate that the surface and subsurface drainage network in the study area are well connected and are responsible for the high erosion rates.

Conclusion

A high-resolution topographic model was created to identify different badland surfaces and drainages features. DEMs were used to identify areas of water erosion in a badland landscape using the terrain attributes of slope, flow accumulation, and stream power index (SPI). Areas of surface and subsurface erosion were identified in the unfilled DEM SPI verified by field data. The DEMs were not capable of detailed recognition of geomorphic features related to subsurface erosion such as pipe shafts and small gullies in the heavily dissected badlands landscape. In both the depression-filled and non-filled DEMs, flow accumulation validity is verified by visual comparison. Two different SPI datasets were created; one representing erosion potential of a filled DEM and the other representing the erosion potential of an unfilled DEM. The SPI calculated with the unfilled DEM showed a poorly connected drainage network, which resulted in less water accumulation and low erosion potential. The field survey documented that most mapped pipes and small gullies function as drainage conduits for surface runoff in the study area. As a result the SPI calculated with the depressionless DEM created a drainage network similar to reality.

Application of the terrain attributes of slope, flow accumulation, and SPI with fill was able to identify areas with a high potential for surface and subsurface erosion by water in the Avonlea Badlands of Saskatchewan, Canada. The results suggest that identifying subsurface erosion processes could help to understand high erosion rates and sediment yield in badland environments.

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Prairie Perspectives: Geographical Essays
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Fields of white: Critical social and spatial analysis in prairie geography

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In the Canadian prairies, where histories of colonization, European settlement and agrarian accomplishment dictate much of the region's cultural narrative, the normalization of whiteness may easily operate without acknowledgement or criticism. By contrast, anti-racist geography calls for the recognition of whiteness as the norm upon which non-white communities are marginalized and oppressed. Here, whiteness studies enable an evaluation of the colonization and racialization of non-white communities, and the manner through which this process reduces their access to opportunities and services. While whiteness studies in geography are growing in popularity across North America, the Canadian prairies offer a unique social, spatial and economic landscape, wherein lower concentrations of visible ethnic minority communities lead to the erasure of these group experiences in social and spatial evaluation. As non-white experiences are not monolithic, this discussion briefly examines the past and present experiences of Chinese-Canadian communities, living with whiteness as a norm. Through an evaluation of whiteness that incorporates both social exclusion theory and applies a lens of civil risk, this article calls for the necessity of critical, anti-racist geographic applications where many may least expect them—the prairies.

Keywords: racism, civil risk, equality, prairie whiteness, Chinese-Canadian

Introduction

Across the various subfields of geographic thought, the presence of critical social analysis in the form of anti-racist scholarship is increasingly influencing the manner through which social and spatial relationships are interpreted. Within the Canadian prairies, a series of marginalized groups exist, whereby intersecting experiences of 'race', 'gender', 'ability', sexual orientation and age further influence one's access to social and spatial opportunity. The experiences of these communities are spatially located, and whilst originating from a series of group histories (many of which host painful oppressions), diverge into socially constructed and situational relevance. This experience of group 'otherness' is developed through a series of functions, including the social production of a normative group, and its power in defining rights of access and equality (Kobayashi and Ray 2000; Guess 2006). The lens through which geographers interpret the nature of social relationships is fundamental to the means whereby their spatial ramifications are understood. Subsequently, recognizing the continued nuances of these varied experiences within physical spaces, social life and institutional structures is key to fully interpreting the design and accessibility of urban prairie spaces. The following discussion highlights the importance of critical race analysis within what Noivo (1998) describes as a 'Euro-ethnic' landscape, and in the absence of large census metropolitan areas (CMAs) that traditionally receive the majority of Canada's non-white 'arrivant' communi-

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ties (Byrd 2014, 175). (Note: the term 'arrivant', popularized by American Indigenous studies and postcolonial researcher Jodi Byrd, is used here to distinguish the difference between both white and non-white immigrant communities to Canada, as well as between non-white Indigenous and immigrant communities). Beginning with a more thorough understanding of the nature of prairie 'whiteness', and further exploring the means through which equal opportunity and access are conceptualized, this discussion enables an evaluation of prairie Chinese-Canadian communities whereby it becomes clear that without a critical analysis of past and future social geographic work, the prairie cities of tomorrow will continue to foster unchecked oppressive landscapes for those outside of the constructed norm.

Despite the prevalence and intricacy of marginalized groups across the prairies, the following article will explore in more detail the manifestation of whiteness in prairie geography, and its implication for the ways in which prairie physical and social spaces are interpreted and experienced by non-white arrivant groups. Though this discussion seeks to emphasize the spatial and social impacts of whiteness upon the non-white arrivant demographic, it in no way aims to overlook or undermine the exceptional damage these geographies of oppression have placed upon Canada's Indigenous communities (Kobayashi and Ray 2000). It is critical to recognize that the notion of whiteness as a cultural norm in the Canadian prairies is largely the result of decades of violent and oppressive colonization of Indigenous peoples, erasing both a dynamic past as well as modern rights to land and self-governance (Frideres 1985; Ponting 1998). The compounding ill effects of this colonialism, and its swift construction of whiteness as a Canadian norm have orchestrated extensive social and spatial harm to these communities (Frideres 1999; McLean 2013). Though the following discussion seeks to provide a critical analysis of the social and spatial relationships between non-white arrivants and the white settler narrative in Saskatchewan, it is important to note that several of the dynamics and societal norms discussed here remain grounded in historic and modern paradigms of colonialism and white ethnocentrism (Ponting 1998). However, fundamental to this analysis is the recognition that although the ill effects of whiteness harm both non-white arrivants and Indigenous communities, treating these experiences as parallel overlooks the past, current and future impacts of colonialism, Indigenous rights to land, the role of arrivant communities in continued colonial paradigms and intergroup racism. Regardless of the focus of this article, readers are encouraged to critically evaluate the influence of whiteness on a broad variety of groups, recognizing that the social and political environments from which these dynamics emerge are unique temporally, socially and spatially.

The significance of prairie whiteness

An anti-racist approach to geography requires in many ways an interpretation of both the dominant group, here defined through whiteness, and the racialized other (Li 1998a, 1999a; Guess 2006). Unlike outdated approaches to race and ethnicity that characterize phenotypic and genetic indicators as meaningful social and economic determinants, the following discussion utilizes social constructivism, a leading paradigm in anti-racist scholarship (Berger and Luckmann 1966; Jackson 1998; Guess 2006). Here, race and ethnicity are understood as the product of power dynamics between differing groups, whereby only those characteristics given social, economic and spatial meaning are subsequently associated as indicators of a particular group (Li 1999b). In effect, though biologically irrelevant, race and ethnicity maintain social meaning and are in this way very real characteristics of constructed social groups (Durkheim 1966). Despite extensive scholarship on the production and implications of race and ethnicity, only more recently has the study of whiteness itself as the norm upon which outside races and ethnicities are compared, received due geographic and sociological analysis (Bonnet 1997, 2000; Jackson 1998; Kobayashi and Peake 2000; Guess 2006; Baldwin 2012). It is important to note that while ethnic minority groups are often distinguished primarily on arbitrary physical characteristics, whiteness extends beyond skin tone, highlighting a racist ideology through which non-white communities are characterized as different and often subordinate to the conceptualized white norm (Dwyer and Jones 2000; Kobayashi and Peake 2000; Baldwin 2012).

In the context of the Canadian prairies, a critical evaluation of the function of whiteness as a norm is fundamental to interpreting the exclusion processes that operate through a distinction between the white and non-white binary. Beginning with the early and continual erasure of Indigenous histories and rights to land, this paradigm has further expanded to impact arrivant groups of non-Euro-ethnic decent. Social exclusion theory, a theoretical perspective gaining increasing relevance in the studies of spatial disadvantage, poverty and institutional access, provides a functional framework through which to interpret this dynamic (Church et al. 2000; Body-Gendrot 2002; Fangen 2010; Lucas 2012). Here, social exclusion is defined by Levitas et al. (2007, 9) as: "…the lack or denial of resources, rights, goods and services, and the ability to participate in the normal relationships and activities, available to the majority of people in a society, whether in economic, social, cultural or political arenas. It affects both the quality of life of individuals and the equity and cohesion of society as a whole." This analytical tool supports the critical evaluation of either the individual or group experiencing social exclusion, as well as the broader normative society within which these individuals reside (Wang et al. 2012). In effect, social exclusion as a theoretical perspective works in tandem with whiteness scholarship, enabling an evaluation of the dominant group in society for its function in the exclusion of 'colonized and racialized others' (Byrd 2014, 176). In the Canadian prairies, this evaluation requires an understanding of the production of whiteness as a norm, conceptualizing how this phenomenon continues to play an operative role in the spatial and social exclusion of non-white arrivants, and evaluating the manner through which spatial distribution and historic trends have worked to exclude these communities from the cultural prairie narrative.

The construction of whiteness in the Canadian prairies

The significance of prairie geographies of whiteness stem from both a more local history of settlement, colonialism and immigrant group narratives, as well as the global production of white privilege and normalization. Though 'geographies of whiteness'—physical spaces that are structured or function through inherent notions and norms of whiteness—are growing increasingly familiar in the geographic field, localized histories and futurities remain key to a functional interpretation of their impact on diverse and spatially located groups (Bonnet 1997; Vanderbeck 2006; Baldwin 2012). For this reason, an analysis of prairie whiteness is an important and lacking addition to existing anti-racist scholarship. While much literature on Canadian pluralism emphasizes the urban spatialities of large CMAs (i.e., Vancouver, Toronto and Montreal), or of the nation as a whole, critical evaluation of whiteness and pluralism in small to mid-size prairie cities remains minimal (Bolaria and Li 1985; Anderson 1991; Henry and Tator 2006; Qadeer and Agrawal 2011; Burayidi 2015). Here, the reduced presence of non-white arrivants and less obvious forms of spatial segregation (i.e., fewer visible ethnic enclaves) fosters an 'out of sight, out of mind' dynamic that further validates the unchallenged notion of prairie whiteness. In contrast, this phenomenon, like all spatial trends, is rooted in both past and present social, political and institutional behaviour.

Settlement history and the prairie normative

A brief examination of Canada's colonialism, immigration patterns and legislation aids interpretation of the normalized whiteness of the prairies. Early settler communities in central Canada were more likely to populate in rural areas, particularly those coming from countries deemed valuable for their comparable agrarian climates. The colonization of the prairies that followed the arrival of these early groups established a region populated largely by settlers from European countries such as Germany, Ukraine and Poland, and the subsequent spatial segregation of existing Indigenous communities (Frideres 1985; Kalbach and Kalbach 1999). While a detailed history of European settlement across the prairies is outside the scope of this discussion, what remains of relevance to these patterns is the manner through which the prairie narrative was quick to ignore existing Indigenous communities, and to overcome cultural and ethnic distinctions between settling groups. Despite the clustering of like-immigrant communities across the prairies, ethnic distinctions between these groups entailed primarily unidirectional processes of language and cultural adaptations, and have been largely erased within an encompassing narrative of whiteness (Waters 1990; Noivo 1998). While modern white prairie dwellers may compare subtle differences in holiday traditions, cultural practices and family lineage, the narrative of whiteness enables these individuals the privilege of choosing which ethnic characteristics they desire to retain or value, and introduces little to no limitation to their inclusion within Canada's dominant society (Waters 1990; Chappell et al. 2008).

By contrast, the settlement history of non-Euro ethnic Canadians demonstrates a far less fluid process of inclusion. Due to the overt discriminatory nature of Canada's immigration legislation, the majority of non-Euro-ethnic immigrants arrived in Canada following the introduction of the 1967 Universal Points System (Bolaria and Li 1985). Though the histories of non-white immigrants in Canada pre-date many European groups, their narratives were diminished by political and social pressures and overt discrimination that led to the numerical restriction and spatial segregation of these groups. An examination of the Chinese-Canadian community helps inform this perspective. For example, after years of enforcing an increasing head tax on incoming Chinese migrants, the Canadian government introduced the Chinese Immigration Act in 1923 that completely banned the inflow of Chinese immigrants until its repeal following World War II (Bolaria and Li 1985; Li 1998b). Not only have such overt racisms harmed the social and economic status of visible minority groups such as the Chinese across Canada, but they have also helped to establish the belief that all non-white, non-Indigenous residents are recent immigrants to Canada. Where notions of property ownership and rights of belonging are used as the foundation for several Canadian civil rights, the perpetual nature through which whiteness paints non-white arrivants as foreign challenges their equal access to opportunity, services and economic success (Kobayashi and Ray 2000). For this reason, several scholars have noted their use of the term 'Chinese-Canadian' to define both recent Chinese immigrants and generations-old Canadians, as these individuals are largely treated equally by the remainder of Canadian society (Li 1998a). Here, whiteness enables the formation of a normalized group, and puts into question the social, political and economic legitimacy of those outside of it. These processes are amplified in the Canadian prairies, where the colonial narrative of agrarian development, struggle and prosperity excludes later arriving non-white immigrants.

The social and spatial exclusion of visible ethnic minority groups

Civil risk and equal rights

Since the introduction of Canada's Universal Points Systems, and a series of nationwide initiatives to value mulled notions of multiculturalism and cultural pluralism, the face of racism towards non-white arrivants has begun to change (Li 1999a). While overt legislations such as the Chinese Immigration Act remain painful artifacts of Canada's past, their lasting impacts and intersecting modern expressions of covert discrimination remain very real components of non-white arrivant life in the Canadian prairies (Bolaria and Li 1985; Zong and Perry 2011; Wang et al. 2012). The continued discrimination experienced by visible minority Canadians is complex, and intersects in nuanced ways with gender, sexual orientation, age and country of origin. As scholars have noted, the experiences of colonized and racialized communities in North America differ dramatically, largely due to their seeming similarities or departures from perceptions of normative and idealized whiteness, as well as one's status as either a 'foreigner' or 'insider' to Canadian society (Waters 1990; Kim 1999). Phenomena such as inter-group racism, political focal points and international relations further complicate the experiences of non-white Canadians.

In an attempt to move beyond the whiteness binary of Canadian race and ethnic relations, this discussion recognizes the inappropriateness of treating all visible minority groups and their experiences as an equal polarity upon which whiteness is continually conceptualized. Though racism and discrimination are fundamental concepts of Canadian social and spatial relations, their nuances may be more appropriately interpreted through a theoretical lens that recognizes diversity in history, experience and access to services (Kim 1999). As an alternative to interpreting non-white experiences as monolithic, particularly between Indigenous and arrivant communities, Kobayashi and Ray's (2000) 'civil risk' helps to reorient the discussion away from formal equality principles that assume equal access is synonymous with equal opportunity and outcome. Here, civil risk allows for an examination of social conditions, whereby the "failure of human rights, brought about by institutional means…creat[es] disadvantages for marginalized social groups" (Kobayashi and Ray 2000, 402). Through this lens, Kobayashi and Ray call for social justice and scholarship motivated by individual and group risk, rather than perceived equal rights.

As anti-racist scholarship recognizes, one's experience with marginalization, here premised on non-white group membership, stands to dictate one's access to social, economic and political opportunity. This social truth contradicts popular Canadian 'rights' arguments founded upon conceptions of equality in terms of both opportunity and outcome. Where notions of multiculturalism and democracy stand to overlook the continued implications of racism on non-white lives, the Canadian narrative dictates a dismissal of the continued implications of whiteness (Henry and Tator 2006). By contrast, recognizing and critiquing whiteness as a norm enables an acknowledgement of the continued systemic oppressions faced by non-whites, particularly when visible minority groups, despite having obtained equal formal civil rights, continue to experience exclusion, discrimination and poverty (Kobayashi and Ray 2000). Once again, social exclusion theory may be applied to interpret how a failure to critique whiteness in social and spatial realms contributes to the disadvantage of non-white groups. As Kobayashi and Ray note, pluralist notions of justice remain at the core of mediating shared spaces, requiring that difference must be recognized and critically evaluated (2000, 414). In the Canadian prairies, this conversation begins with an acknowledgement of prairie whiteness, and its ability to overlook the injustices experienced by Indigenous and non-white arrivant groups.

Covert racism and modern non-white disadvantage

While the legislative and overt expressions of racism that characterized the earlier half of the twentieth century began to diminish, and World War II taught many nations the dangers of racialized discrimination, changes in the Canadian paradigm fostered a series of more covert expressions of racism (Bolaria and Li 1985). As discussed above, the realities of modern non-white Canadians vary in accordance to unique historical and modern experiences with discrimination, their level of perceived difference from normative whiteness and their subsequent civil risk. Despite this, an evaluation of the experience of Chinese-Canadians, in line with the aforementioned examples, highlights the dangers of whiteness for non-white arrivant prairie communities, spurring from an erased historical context as well as modern systems of white privilege.

Early institutional and overt racisms, in the form of legislative restrictions on immigration, employment and political activity of the Chinese community severely impeded the group's integration into early settler Canadian society (Li 1998a; Zong and Perry 2011). With initial waves of Chinese immigrants arriving largely in response to labour shortages surrounding the construction of the Canadian Pacific Railway, early anti-Chinese legislation was released to coincide with the completion of this project (Li 1998a). In addition to the aforementioned Chinese Immigration Act, these early communities were restricted from participating in a large majority of profitable economic ventures, resulting in a concentration of Chinese owned groceries, laundries and restaurants, and their subsequent poverty (Bolaria and Li 1985; Li 1998a). In addition to forced economic insularity, social discrimination towards Chinese-Canadian arrivants pushed early communities into spatial isolation, largely as a defence mechanism against the pervasive violence of Canadian whiteness. Despite entering Canada during a time of mass immigration and cultural diversity, a Eurocentric system of privilege and rights of access were already in place. While many Chinese-Canadians first arrived in Saskatchewan in an attempt to escape the discrimination and oppression they faced along Canada's west coast, existing prairie whiteness fostered a landscape no more welcoming. Here, in addition to continued social and economic segregation, Chinese arrivants faced further discriminatory legislation that would remove provincial and federal voting rights, and prohibit the employment of Caucasian women in Chinese owned businesses (Dawson 1991; Backhouse 1994). An application of social exclusion theory enables an understanding of the subsequent retention of Chinese cultural and language characteristics, not as inherent qualities of this group, but as the result of white ethnocentrism and paralleled non-white discrimination. In effect, cultural isolation and a reliance on internal group support systems have fostered Chinese-Canadian social and spatial segregation from dominant Canadian society, in both historic and modern contexts (Lee 1987; Chau and Lai 2011).

Despite a history of racialization of the Chinese-Canadian community that was initiated during a time where overt discrimination was normalized at both individual and governmental levels, its legacy has remained with the Chinese-Canadian community for generations to follow. Continued social, economic and political ramifications of this early discrimination, in addition to the erasure of Chinese-Canadian heritage from many Canadian—and particularly prairie—narratives enables this continued exclusion to appear as an inherent cultural characteristic of the

Chinese-Canadian community, as opposed to the result of normalized whiteness. Unfortunately, those who remain most distant from dominant cultural norms are often most distant from society's affluence and social services (Lee 1987). Language and cultural 'otherness' of Chinese-Canadians, especially within the group's older generations, have proven to exist at the cost of health, wellbeing, economic opportunity and social inclusion (Lee 1987; Butler et al. 1998; Lai 2004; Chappell et al. 2008; Hwang 2008; Chau and Lai 2011; Wang et al. 2012). In examining access to service provision and programming catered to Saskatchewan's Chinese-Canadian community, recognizing the group's isolation from various opportunities as a result of prairie whiteness, and not merely group preference or culture, is fundamental. Anti-racist scholarship enables a respect for the history, present and future of non-white arrivant groups, such as the Chinese-Canadian community, as well as an effective evaluation of their presence in social, physical and institutional spaces.

For geographers, a failure to recognize the manner through which prairie whiteness has, and continues to, impact the lives of visible ethnic minority groups stands to reduce the quality of scholarship in many ways. Firstly, without examining whiteness as a norm, geographers may fail to recognize the production of social and spatial ethnic communities as a defense mechanism against the discriminatory behaviours of the broader society (Anderson 1991). Further, geographers may over estimate the capacity of these communities to care for their more vulnerable members, interpreting the absence of non-white arrivants from health, financial and housing institutions as a sign of self sufficiency as opposed to an indicator of exclusion (Lee 1987; Chau and Lai 2011). Particularly in the prairie context, where ethnic enclaves are often less dramatic or established, the tendency to assume that non-white arrivant Canadians have the resources within their cultural communities to ensure the health and wellbeing of their residents exists at the detriment of these individuals. In other instances, geographers may be inclined to see the lack of large ethnic communities in prairie cities as an indicator of cultural assimilation and the reduction of a white/non-white binary. Here, without an appropriate understanding of non-white civil risk, geographers may further assume that equal access and opportunity to spatial and social initiatives will be equally beneficial to diverse residents of a community (Kobayashi and Ray 2000). Alternatively, recognizing that prairie whiteness stands to normalize and prioritize those who speak English or French as a first language, practice western religions, have Euro-ethnic names, and maintain physical indicators of group inclusivity (i.e., Euro-ethnic phenotypic characteristics) highlights the accompanying disadvantage for those who do not. If left unchecked, a failure to acknowledge the characteristics of whiteness as contributors to the exclusion of Canada's racialized and colonized communities may remain one of the largest detriments of prairie geography.

Conclusion

Prairie geographers, in their evaluation, interpretation and production of space, must work to acknowledge the function of whiteness as a norm from which social and spatial situations are understood and acted upon. Whiteness impacts many strands of geographic research, and subsequently the lives of colonized and racialized individuals who stand to benefit from the product of these works. Without a critical awareness of whiteness as a norm, the exclusion of non-white communities from spaces, social organizations and institutions may appear as inherent or natural qualities of these groups. By contrast, applied lenses of social exclusion theory and civil risk enable geographers to identify the manner through which the activities, characteristics, and values of normalized whiteness function in the denial of opportunity to non-whites. While evaluations of whiteness grow in popularity across much of the field of geography, unique attention must be paid to the implications of prairie whiteness, where a colonial cultural narrative of agrarian and European history goes largely unchecked, impacting both the realities for Indigenous communities and non-white arrivants, as well as the dynamics within and between these groups. Geographers must recognize that the absence of well established non-white arrivant communities in many Canadian prairie cities may not be an indicator of equal opportunity or 'colour blindness', but instead of historic discriminatory legislation and of continued group marginalization that is overlooked due to less obvious spatial indicators. In the planning and development of prairie communities, critical anti-racist evaluation enables both questions of rights and ownership to land and space, while further empowering the development of institutional initiatives and social outreach programs through which geographers must acknowledge the continuing danger of an unchecked white narrative, and its capacity to disadvantage both colonized and racialized community members. To truly benefit the spaces of the prairies as a whole, anti-racism in geography must remain at the forefront of existing and upcoming scholarly and applied initiatives.

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The spatial pattern of gentrification in Berlin

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In recent years, gentrification has become central to political debates, media reports, and everyday conversations on urban development in Berlin, Germany. More or less all inner city districts fit some rubric of gentrification discussed in the international literature. However, as a result of Berlin's unique history as a divided city, the process has developed at times and in patterns that are markedly different from other global cities. The article briefly outlines the urban agendas and renewal efforts of East and West Berlin during the years of division. It proceeds to document the political, economic, and cultural factors underlying the development of Berlin's place and history specific development of gentrification in the reunified city since 1990.

Keywords: Gentrification, spatial pattern, Berlin, Germany

Introduction

At first sight, Berlin appears to be a showcase for the various forms of gentrification discussed in international literature (Holm 2013, 186). In different districts, examples of 'new-build gentrification' (Davidson and Lees 2010; Marquardt *et al*. 2013), 'super gentrification' (Lees 2003) and 'rental gentrification' (Van Criekingen 2010) are evident. In addition, elements of 'tourism gentrification' (Gotham 2005) or 'new urban tourism' (Füller and Michel 2014) can be observed. However, the many different forms of gentrification in Berlin should not be viewed as ubiquitous developments occurring in a vacuum. Nearly three decades of division by the *Mauer* (the Berlin Wall) influenced the evolution of waves of gentrification and are responsible for today's very specific spatial pattern of gentrification in Berlin. Gentrification is a global phenomenon first identified by Ruth Glass (1964) in the inner city of London, UK during the 1960s. It can now be found in many major cities of the western hemisphere, including Canadian cities such as Toronto, Montreal, and Vancouver (e.g., Ley and Dobson 2008; Walks and Maaranen 2008). While each city has its specific spatial and temporal pattern of gentrification, this article traces the spatial development of gentrification in Berlin back to the city's place-specific history of urban planning strategies. It begins with an outline of the political climates and urban renewal efforts of East and West Berlin during the Cold War forming the backdrop for gentrification in the city. It continues with an examination of the spatial dynamics of gentrification since German reunification (1990), first among inner city districts of former East Berlin where gentrification unfolded, and afterward in those of former West Berlin, to where the process has since diffused. The article concludes with an analysis of potential spatial development of gentrified areas in Berlin.

Berlin – pre reunification

Unlike most Western capitalist cities, gentrification was of relatively little significance in Berlin until the mid-1990s, and its development today cannot be detached from an understanding of the housing and renewal policies during the Cold War in each of East and West Berlin.

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During the years the city was divided, real estate in socialist East Berlin had increasingly come "under state ownership through confiscation [the largest of which was carried out by Soviet authorities in the late 1940s]; as owners, unable to manage their properties given the many restrictions, simply turned their deeds over to the state; and as families fled to the west, leaving their property behind" (Strom 2001, 64). Although private property ownership had not been abolished under the German Democratic Republic (GDR), the buying and selling of real estate was severely limited because the vast majority of property was publicly owned (Strom 2001). Thus, displacement by rising rents was not an issue in East Berlin because a developed housing market driven by opportunities for profitable redevelopment was simply non-existent.

What occurred in East Berlin was massive, state-driven depreciation of central city real estate. Inner city neighbourhoods with old housing were ideologically devalued as epicentres of capitalist urban development, and housing policy favoured new high-rise developments that embodied socialist ideals (Levine 2004). Under the GDR, those more successful in the system moved out to the belt of high rise apartments made of prefabricated concrete slabs on the east side of the city (e.g., Berlin Marzahn) where greater living space, heating, and insulation, as well as better access to amenities and public services were offered (Levine 2004). The older inner city housing stock meanwhile deteriorated as the GDR kept rents too low to finance much needed renovations—a situation exacerbated by the limited availability of building materials. Nearly all residential buildings in the former inner city district of Prenzlauer Berg, for example, were characterized by squalid living conditions, lacking even basic amenities such as central heating and bathroom facilities (Levine 2004). The deliberate neglect of the inner city by the socialist state was accompanied by high vacancy rates; up to 20 percent of apartment buildings in some areas of inner East Berlin were vacant (due to being unsafe and uninhabitable) at the time of reunification in 1990 (Holm and Kuhn 2011). With this out-migration, East Berlin's 'alternative scene' took refuge in the tenement neighbourhoods, and areas like Prenzlauer Berg "gained the reputation for being the sort of East German version of [New York's] Greenwich Village or [San Francisco's] Haight-Ashbury, a place of intellectuals, artists, [and] counter-cultural lifestyles" (Levine 2004, 92).

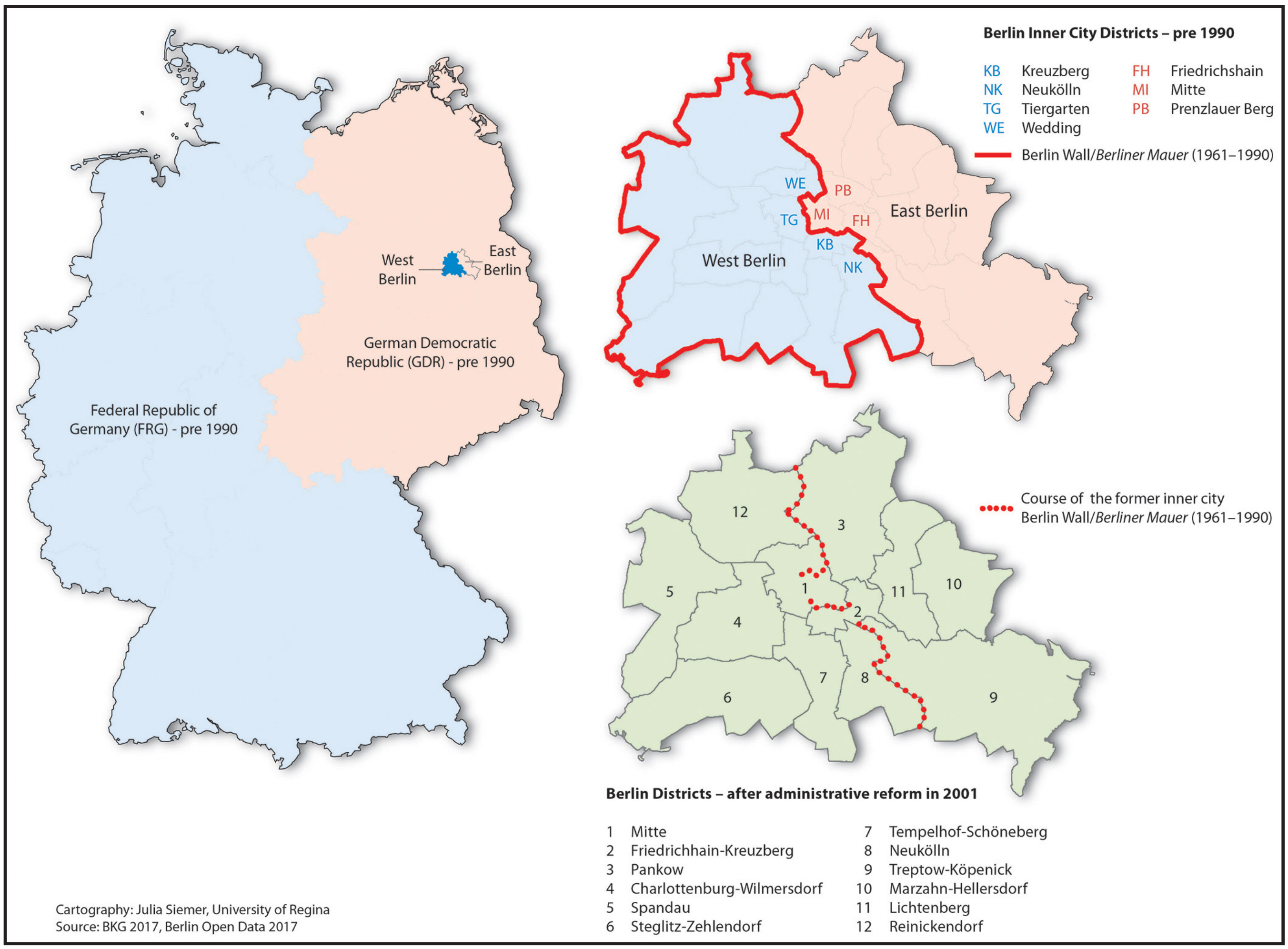

Figure 1
Berlin – Location and administrative organization

West Berlin, as an entity heavily influenced by capitalist West Germany (i.e., the Federal Republic of Germany (FRG)) but isolated within socialist East Germany (Figure 1), was "cut off from its hinterland, surrounded by hostile armies, [and] robbed of its capital functions and industrial base…Its isolation from the West and the constant threats to its security prevented the city from attracting sufficient economic activity to survive" (Strom 2001, 79). As such, the economic viability of West Berlin, and therefore its urban (re)development, depended largely on West German state subsidies (Strom 2001). The primary goal of planners in West Berlin during the postwar period was to create abundant, affordable housing on the urban periphery, which coincided with the overarching, modernist planning philosophy of dispersing people from dense inner city neighbourhoods to create homogeneous residential zones (Strom 2001). After the construction of the Mauer in 1961, the West Berlin government started an ambitious urban renewal program with plans that called for the wholesale demolition and rebuilding of particular inner city districts that were home to approximately 140,000 residents (Strom 2001).

The marginal position of inner city neighbourhoods near the heavily armed border to East Berlin, combined with the city's 'raze-and-rebuild' strategies for renewal, halted investment and led to a massive devaluation of inner city property in West Berlin's districts such as Kreuzberg and Wedding (Füller and Michel 2014). The city-controlled, limited-dividend housing companies in West Berlin continued to buy out owners and relocate tenants to the suburbs. However, in the wake of the economic crisis of the early 1970s, "the funds for demolition and construction were not forthcoming. Cleared lots and empty buildings sat idle, leaving remaining residents with a sense of despair" (Strom 2001, 49). Perhaps the most radical form of civic unrest came from the squatter movement of the early 1980s, when the number of squatted buildings in West Berlin grew from 21 before the end of 1980 to nearly 170 by the summer of 1981 (Holm and Kuhn 2011). This resistance ran parallel to the massive housing shortages in West Berlin, where some 80,000 people were registered as seeking apartments in 1980 alone (Holm and Kuhn 2011).

Politically organized tenants, a strong squatter movement, and housing shortages, together with limited funding opportunities led city officials to consider alternative and less capital-intensive renewal efforts. Thereafter the city's raze-and-rebuild strategies were replaced with a 'cautious urban renewal' strategy. This shift in policy brought about a new model of renewal based on the preservation of existing housing structures and the social composition of the population, in addition to encouragement of citizens' participation in the renewal process (Holm 2013). Cautious urban renewal achieved considerable success in renovating housing stock and infrastructure in West Berlin such that a functioning real estate market was restored while avoiding rent increases and displacement (Holm 2013; Füller and Michel 2014). Because refurbishment was carried out almost entirely with public funds, rental obligations (e.g., rent caps) had to be accepted by those receiving subsidies for renewal (Bernt 2012).

Spatial pattern of gentrification in Berlin

Berlin's inner city has experienced a unique pattern of gentrification featuring a spatial expansion in a circular, clockwise fashion (Figure 2; Holm 2013). The concentration of newly-opened 'pioneer' facilities (e.g., bars, clubs, art galleries that are geared toward middle-class professionals who often work in the fields of media, design and digital technologies, and young artists) has shifted from one subdistrict to the next, roughly every five years. It depicts how neighbourhood revalorization began in Kreuzberg (West Berlin) during the 1980s amidst the phase of cautious urban renewal, and then shifted to Mitte and Prenzlauer Berg (former East Berlin) during the 1990s, only to arrive in Friedrichshain (former East Berlin) and northern parts of Neukölln (former West Berlin) in the last decade. Figure 3 illustrates an additional pattern, a side presence of different forms and phases of gentrification in Berlin (Holm 2013). For example, the new building projects in Mitte and Prenzlauer Berg are evidence of more intensified forms of gentrification, while the recent influx of young, educated, economically marginal, and creative types in nearby Kreuzberg, as well as the locality's rising but still relatively affordable rents, indicate a more rudimentary, pioneer phase of gentrification (Holm 2013).

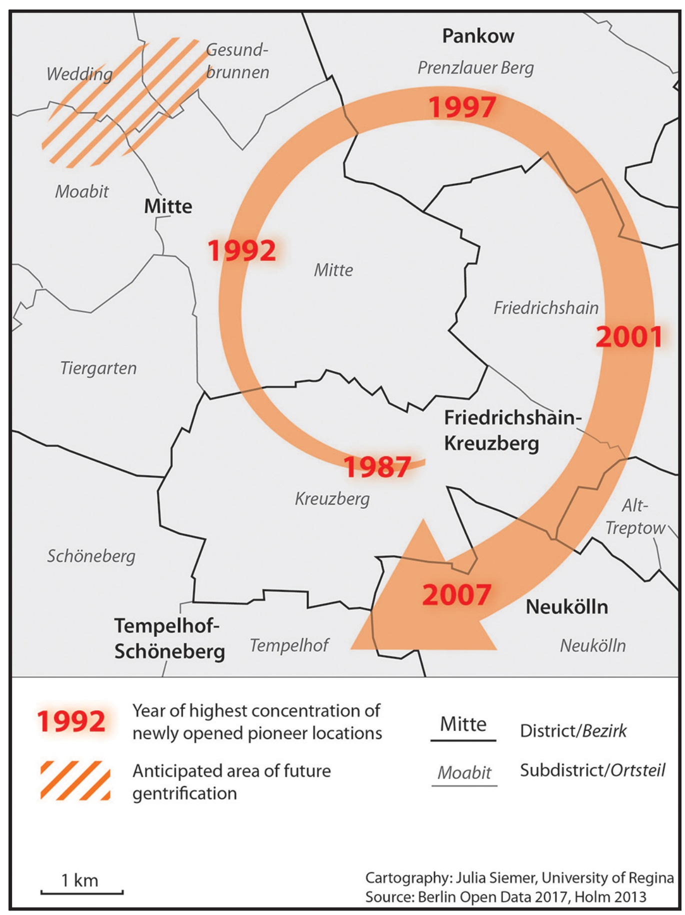

Figure 2
Cycle of gentrification

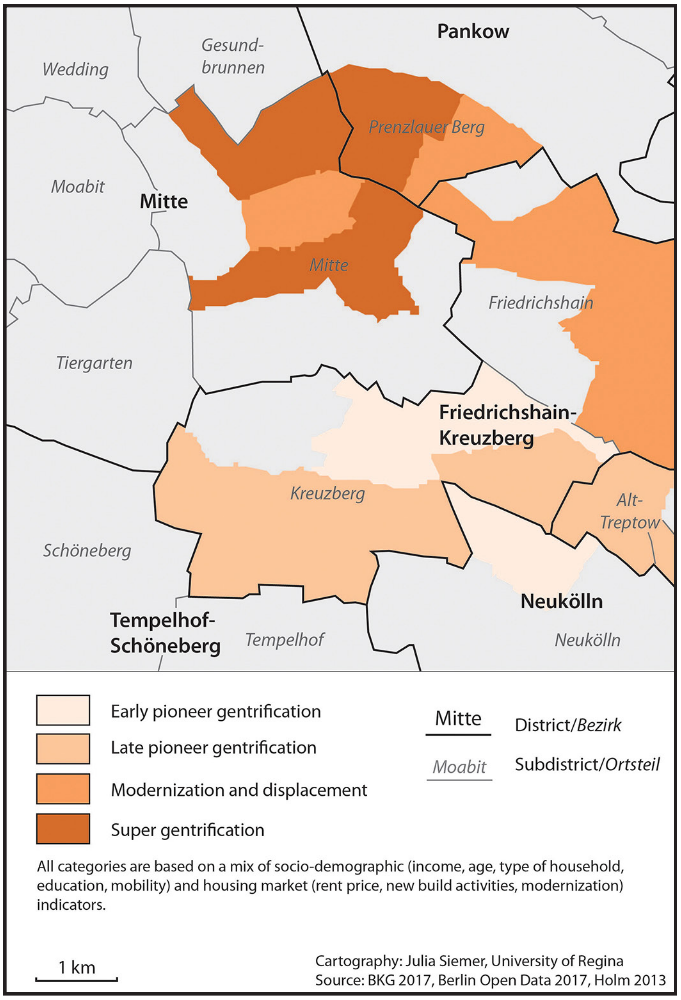

Figure 3
Phases of gentrification

Restitution and rehabilitation in East Berlin

To analyze the spatial dynamics of gentrification in Berlin, it is essential to understand the process of restitution and rehabilitation that took place in East Berlin (and the entire GDR) after German reunification.

With the signing of the Unification Treaty in 1990, previous owners of property that was expropriated between 1933 and 1989—under the auspices of the Third Reich, the Soviet Military Administration in Germany, or the GDR—obtained the ability to lay claim to their confiscated property (Reimann 1997). Despite the complications pertaining to the restitution of property rights, what followed was the creation of a private property market in East Germany. Not only was "the creation of investment incentives" cited as one of the main motives behind property restitution (Häußermann 1998, 95), but the Federal Republic of Germany sought to further stimulate investment through various tax subsidy programs. Building owners were able to write off 50 percent of investment costs on any commercial or residential development in East Germany until 1996, which then dropped to 40 percent until 1999 (Strom 1996). As a result, Häußermann noted that "those who buy property, at least in the inner cities, are no longer private individuals…Rather, these properties are being bought primarily by international real estate companies, or anonymous real estate funds, which are mainly interested in the extra tax deductions to be gained by investment" (Häußermann 1998, 97f). Between 70 and 90 percent of returned property in East Berlin, much of it concentrated in the districts of Mitte and Prenzlauer Berg, was quickly sold to real estate companies, brokers and developers (Bernt 2012). Therefore, the restitution of property resulted not just in the privatization of housing in East Berlin, but "also fuelled a speculative bubble that exerted a high pressure on existing rental and sale prices" (Bernt 2012, 3055).

Despite the economic pressures of the speculative real estate market, rent levels remained low during the early 1990s. To some extent this was a consequence of the gap between the formal claim and the actual realization of restitution (Bernt 2012). Nevertheless, it also reflected an attempt by local authorities to maintain the existing residential structure and keep rents affordable given that significant pressure for rehabilitation was being exerted on those inner city neighbourhoods where housing had become derelict due to East German state policy. Five areas of the district of Prenzlauer Berg, for example, were targeted and formally declared redevelopment zones; the former district itself earned the reputation of being Europe's largest urban renewal area (Bernt 2012). Concerned local authorities initiated modernization activities in Prenzlauer Berg which were largely financed by, and organized through, public programs. In fact, one sixth of Prenzlauer Berg's entire housing stock was rehabilitated through public grants (Bernt 2012). For the duration of the grant programs (which in some cases lasted up to 20 years), the local housing market contained "a considerable 'welfare segment' where rent development, occupancy and the economic profitability of investment were largely disconnected from market activities" (Bernt and Holm 2005, 111f; Bernt 2012).

By the mid-1990s, however, after the speculative property boom had ended, public subsidies were cut. Economic constraints at the federal level put much of Berlin's social programming in a stranglehold, as programs like social housing subsisted largely on federal aid (Levine 2004). Declining land prices (which began falling in 1994) further reduced municipal support "for social programs associated with redevelopment, as the funds for those programs had largely come from the proceeds of redevelopment land sold to private developers" (Levine 2004, 102). Consequently, rehabilitation in Mitte and Prenzlauer Berg depended increasingly on incentives embedded in federal tax legislation. As Bernt points out, federal tax incentives comprised "high, indirect subsidies [that] made the refurbishment of old housing stock extremely lucrative for investors with a large taxable income, especially if costs were high and rents low, since the costs of investment could be transformed into tax savings for the partners involved" (Bernt 2012, 3055). Because the high costs of investment would be offset by tax savings, investors were encouraged to invest as much as possible to maximize their return, and even to rehabilitate properties in areas where affluent demand was not foreseen (Bernt 2012).

Thus, the share of privately financed refurbishment in Prenzlauer Berg increased continuously, accounting for two thirds of total refurbishment throughout the 1990s (Bernt 2012), and evidence of gentrification began to surface by the turn of the millennium. By the end of the 1990s, for example, half of the tenants in privately modernized housing moved into Prenzlauer Berg after refurbishment, and paid rents twice as high as previous tenants (Holm 2006; Bernt 2012). Meanwhile, 85 percent of new renters were between the ages of 18 and 45 years (Holm 2006). Other interesting neighbourhood changes that occurred during the 1990s included the 20 percent increase in single-person households and hence the decline in the average number of persons per household from 2.1 to 1.6 persons (Bernt and Holm 2005). Most astounding was the rise in the educational status of residents; between 1991 and 2000, the number of residents with *Abitur* (higher education matriculation qualification) nearly doubled, and the number of residents with university degrees more than doubled, from 15,500 to almost 35,000 (Bernt and Holm 2005).

Notwithstanding, income levels in Prenzlauer Berg remained well below the Berlin average, a phenomenon that underscores the uneven geography of investment and displacement. Bernt and Holm (2005) argued, for example, that below-average income in the 1990s tended to hide significant differentiation within the area, as there existed a large gap between the rich and poor unlike anywhere else in the city with "high and low earners liv[ing] cheek by jowl" (Bernt and Holm 2005, 116).

After 2000, the course of urban renewal in East Berlin changed considerably. With the disappearance of federal tax incentives in 1999, profitable reinvestment in Mitte and Prenzlauer Berg began to rely on the transformation of rental housing into single-ownership. This, prompted landlords to develop project plans, call for owners, and then begin refurbishment activities after securing bids for the projected units (Bernt 2012). In the complete absence of public expenditure and tax reductions, previously rented apartments were converted into upscale condominiums using funds from their future inhabitants. As Bernt (2012) points out, this model of renewal proved to be very popular among investors; one third of all housing in the designated redevelopment zones of Prenzlauer Berg were transformed into condominiums between 2000 and 2010 (Bernt 2012). Paralleling this shift in investment strategies, another trend in housing emerged in the mid-2000s in which new building projects have been increasingly undertaken on empty lots and open spaces. For example, since 2005 at least 27 new luxury apartment and/or condominium complexes, with a total of 1250 units, have been constructed or are undergoing construction in Mitte and Prenzlauer Berg (Holm 2013).

As subdistricts Mitte and Prenzlauer Berg transitioned into new-build or super gentrification, the subdistrict of Friedrichshain became the new pioneer location. As the site of major postwar renewal, Friedrichshain was not explicitly earmarked for redevelopment like Mitte and Prenzlauer Berg, and gentrification dynamics were restrained in the years following reunification (White and Gutting 1998). It was not until the late 1990s that it was celebrated as the new 'scene' quarter—compared with neighbourhoods in Mitte and Prenzlauer Berg that were by then described as established and boring (Holm 2011). Changes to the social composition were most pronounced at first in terms of the rising share of residents with high educational status (Krätke 2013). Modernization activities, on the other hand, were delayed. Nevertheless, comprehensive modernization has taken place, resulting in significant increases in rents (Holm 2011). Moreover, countless bars and clubs shaped the image of Friedrichshain, and their increasing commercialization leaves little room for the traditional corner pubs that once occupied the area (Holm 2011). Friedrichshain has thus undergone its pioneer phase, evidence of displacement has surfaced, and, as in Mitte and Prenzlauer Berg, this will likely continue unevenly according to the geography of private investment in the subdistrict.

The end of 'Cautious Urban Renewal' in West Berlin

West Berlin in the 1990s was marked by suburbanization and urban sprawl with middle and upper-income groups migrating out of the city, which, prior to 1990, was encircled by the Mauer (Füller and Michel 2014). Although there were concerns that inner city districts of West Berlin would undergo rapid gentrification—particularly Kreuzberg with its low rents, history of radical and alternative subculture, and sudden central location in the returned capital—these fears did not materialize (Füller and Michel 2014). Rather, throughout the 1990s, Kreuzberg faced a rise in unemployment, increased poverty and overall decline (Füller and Michel 2014). Of central importance to Kreuzberg was its history of cautious urban renewal. The program's long-term rental agreements, which established rent caps as preconditions for modernization, kept rents at affordable levels for some 15 to 25 years (Holm 2013). The principle of cautious urban renewal thus performed the dual function of upgrading Kreuzberg's most seriously devalued housing and infrastructure while retaining the former district's original working class residential structure.

More than 20 years after cautious urban renewal, today's subdistrict of Kreuzberg is faced with so-called rental gentrification (Van Criekingen 2010). According to Holm (2013), German tenancy law strongly protects residents from rent increases resulting from modernization unless it entails a wholesale transformation of the standard of housing (as in Mitte and Prenzlauer Berg). Hence, even today there is little leeway for rent increases in the context of modernization since substantial amounts of property were upgraded to a relatively high standard in the 1980s. Contrary to modernization and super gentrification in East Berlin, Holm contends that the 'rent gap' and resulting displacement pressure in Kreuzberg is largely based on the difference in rental prices between long-term rental agreements and new rental contracts (Holm 2013). Changing ownership exacerbates the pressure for displacement "since the buyers usually see the buildings as an investment whose worth should be realized through replacement of former tenants in order to close a new contract or rather through the transformation of rental properties into sale properties" (Holm 2013, 179).

Building on Holm's argument, Füller and Michel (2014) note how the transformation of rental properties into holiday apartments, which are periodically visited by their owners but otherwise rented out on a short-term basis, has become a popular investment scheme for individual buyers in Berlin and particularly in Kreuzberg. Short-term rental, they argue, "promises higher revenue and avoids dealing with the strict German tenancy law if considered against a traditional buy-to-let scheme. Weekly rates typically resemble the monthly rates for long-term rent and private vacation rental does not have to fulfill the costly security standards and tax payments of a professional hotel or hostel" (Füller and Michel 2014, 1312).

It is speculated that the increasing number of holiday apartment in Kreuzberg is related to growing touristic interest and the particular demands of so-called new urban tourism. Unlike ordinary tourism, new urban tourism deals with a specific kind of urban experience where staged experiences in officially sanctioned tourist spaces are avoided. Instead, the passive consumerist notion of everyday and mundane tourism is "replaced by an active search for new and unusual personal experiences and for being part of the visited place and lifestyle ascribed to it" (Füller and Michel 2014: 1306). Oftentimes, these experiences are found in working-class, ethnically and gastronomically mixed inner-city neighbourhoods whose diversity and gritty character contributes to the sought-after authenticity of urban places (Füller and Michel 2014). According to Füller and Michel, in Kreuzberg "the history of immigration, an abundance of small grassroots culture and entertainment venues, a leftist history and a well-preserved housing stock due to cautious urban renewal all make for a socially diverse and amenity-rich [sub]district, which is especially attractive to the new type of tourists" (Füller and Michel 2014, 1309). In addition, Kreuzberg's diverse and rugged character encapsulates much of the 'creative' and 'poor but sexy' mantra the city has used since the early 2000s to promote growth in the single most important sector of its economy—tourism (Füller and Michel 2014).

The trend of converting long-term into short-term rental apartments, while relished by new tourists, is a veritable problem for residents. The growing number of holiday apartments in combination with the absence of any new-build activities means fewer living options are available to residents and increasing pressure on existing long-term rental prices is exerted. The number of housing units per 100 households dropped from 93 to 81 between 2005 and 2009 alone (Holm 2013), thereby indicating that the availability of housing in Kreuzberg is already shrinking. On the other hand, the residential population in Kreuzberg remains relatively poor; about 30 percent of households have a monthly income under the poverty line (Holm 2013), and tenants in some areas are already obliged to commit up to one third of their monthly budget for rent (Füller and Michel 2014). As long-term rental agreements expire, it can only be expected that low-income residents will search out more affordable options elsewhere. In short, while substantial displacement of poor and working class residents has not yet taken place, the phenomenon of new urban tourism and short-term holiday apartments aggravates the increasingly hot competition for affordable housing in Kreuzberg.

Southeast of Kreuzberg, in the northern part of Neukölln, there are indications of a similar dynamic; the term 'Kreuzkölln' is, in fact, often used in real estate advertising to indicate these smeared boundaries (Füller and Michel 2014). Like Kreuzberg, the district of Neukölln has a strong migrant background, having been a major recipient of 'guest workers' from Turkey in the 1960s, as well as the destination for political refugees from former Yugoslavia and Lebanon (Hentschel 2015). Neukölln was also characterized by poverty and decline in the 1990s being hit particularly hard when "its last factories and department stores were moved to the cheaper outskirts of former East Berlin, and municipal support was discontinued and transferred to urban renewal initiatives in the East Berlin districts" (Hentschel 2015, 82). Today, the district is still characterized by one of the highest proportions of immigrants and low-income households in Berlin (Holm 2013). Moreover, like Kreuzberg, Neukölln has become something of a new urban hotspot for international artists, students, and tourists in the last decade (Holm 2013).

Füller and Michel (2014) note how, despite Neukölln having been described for decades as a ghetto plagued by crime and decay, "local and international newspapers and city magazines [have] increasingly depicted the northern parts of Neukölln and the east of Kreuzberg as a diverse, cosmopolitan and liberal neighborhood, as the most interesting place to be and 'the epicenter of cool'" (Füller and Michel 2014, 1309). In turn, Neukölln has attracted a considerable number of young Europeans and North Americans in recent years. Between 2010 and 2011, Neukölln received a net gain of 6741 non-German residential moves from abroad, which accounted for nearly 27 percent of Berlin's total immigration that year, but experienced a net loss of 711 domestic residential moves (by all nationals) (Holm 2013). Meanwhile, Berlin as a whole received a net gain of 2195 immigrants from Turkey, which accounted for only 11.5 percent of Berlin's total immigration (Holm 2013). Even if all immigrants from Turkey to Berlin that year settled in Neukölln, they would have comprised less than one third of the district's total residential moves; this is to be compared with immigration from European countries, which was nearly double the district's total residential moves during the same period (Holm 2013). In other words, in Neukölln there has been "a strong impact of moving-ins from EU countries and North America, whereas the traditionally strong migration relation to Turkey is only subordinated today" (Holm 2013, 181).

While Neukölln attracts a type of new tourist, the district has also drawn a large number of creative expats, for whom the length of their stay cannot be accommodated by a mere holiday apartment. In consequence, the long-term rental market in Neukölln is grounded on an unprecedented internationalization (Holm 2013). While apartment prices stagnated prior to 2011, average prices in Neukölln have since more than doubled for smaller apartments and even tripled for larger apartments (Guthmann Estate 2015a). What renders the situation particularly problematic is the absence of the previously applied principle of cautious urban renewal. The housing stock has undergone significant depreciation; internationally positioned realtors are advertising how the "district still has an enormous un-renovated housing stock offering many good investment opportunities" (Guthmann Estate 2015a). And like Kreuzberg, higher rents are being negotiated in new contracts but at a much faster pace given the absence of established rental protections (Holm 2013). The Berlin state government (Berlin Senate) has also sought to capitalize on the changing residential mobility by upgrading the district's functional and gastronomical diversity, having declared the once-renowned shopping area along Karl-Marx-Straße a redevelopment zone in 2011 (Hentschel 2015). The relative absence of rental protection in combination with state efforts to establish an infrastructure for conspicuous cultural consumption, the growing number of expats, and an un-modernized housing stock makes Neukölln a new chapter in the development of gentrification in Berlin.

Future developments

An overview of the spatial dynamics of gentrification in Berlin illustrates how the restructuring of the inner city is shaped not only by an outward diffusion of gentrification, but also by a constellation of different phases and forms of gentrification which are all inextricable products of Berlin's history of urban politics and renewal strategies. The development of gentrification in former East and West Berlin, while markedly different, underscores the importance of local and national governments in harnessing, preventing, and moderating the economic pressures for displacement.

Due to gentrification in Berlin being shaped by the city's history of local and national state intervention (and lack thereof) in the housing market, new developments must be noted. On June 1, 2015, Berlin became the first city in Germany to implement new federal rent cap legislation, and landlords are now prohibited from increasing rents by more than 10 percent above the average in their localities (Oltermann 2014). Such protections were already established for existing tenants but have now been extended to new rental contracts (Russell 2015). The law is not without its criticisms, and it will take some time to determine its effectiveness. However, rental gentrification may become less significant in the future since property owners can no longer charge exorbitantly high rents that are backed by affluent international demand. In the short run, however, higher rents will still be realized in new contracts, as the rents in long-term agreements surely fall below the present-day average in most inner city districts. In addition, newly-built properties and properties that undergo wholesale modernization are exempt from the law's restrictions (Oltermann 2014). Therefore, not only will gentrification in Berlin continue to rely on rent gaps that emerge from un-modernized housing, but perhaps the trend of transforming long-term into short-term rental apartments will take on a greater significance in Kreuzkölln.

After an examination of the development of gentrification in Berlin, it becomes apparent that the former district (and, more specifically, today's subdistrict) of Wedding is the most obvious candidate for future gentrification processes (Figure 4). Along with Kreuzberg and Neukölln, the former West Berlin district of Wedding is traditionally working-class in nature, comprised largely of low-income households, and is one of the most ethnically diverse localities in Berlin (Jakob 2011; Guthmann Estate 2015b). A mixture of industrial and residential buildings characterizes the area. These include the classic, rehabilitation-prone Wilhelmian style tenement houses in addition to high numbers of empty and/or neglected properties (Jakob 2011; Degewo 2015). The relatively poor population, relatively high vacancy rate, and peripheral location means rents in the former inner city district are cheap in comparison to others; average rental prices today are less than half those for the neighbouring subdistricts of Mitte and Prenzlauer Berg, as well as the former district (to be distinguished from today's subdistrict) of Tiergarten (Guthmann Estate 2015b). In recent years, an artistic and cultural scene has established itself in the area, where the inexpensive apartments and commercial spaces have attracted a large group of so-called pioneer artists and students.

Jakob (2011) believes Wedding is the centre of an arts-led neighbourhood revitalization. She examines a joint initiative between a municipal-led neighbourhood management organization and a major real estate holder that organizes monthly 'art walks' through the Sprengelkiez neighbourhood, one of the neighbourhoods in the subdistrict of Wedding most closely associated with gentrification. Vacant properties are supplied by the realtor to artists at operating costs (near zero rents), and artists transform the spaces into non-commercial art galleries. Visitors are then personally guided from one neighbourhood to the next and encouraged to perceive and reimagine the area as creative (Jakob 2011). According to Jakob, in reality this initiative "is regarded as a 'model of success' not for its artistic achievements but because it creates positive attention, lures visitors, publicizes creativity and liveliness and generates hope for gentrification" (Jakob 2011, 197). Jakob's study underscores how municipal efforts are being made to stimulate reinvestment in a neighbourhood the city believes has "special development needs" (Jakob 2011, 196).

Wedding can thus be viewed as ripe for gentrification. As more so-called pioneers move north-west from Mitte and west from Prenzlauer Berg in search of affordable apartments, more infrastructure for cultural consumption will follow. Moreover, with comparatively low rents and a vast number of buildings in need of renovation, investment opportunities are believed to be almost unlimited for real estate investors and property owners (International Network of Urban Laboratories 2013). Given that it is one of only a few former inner city districts whose original character remains unchanged, it is argued that Wedding will be the next area in Berlin's inner city to undergo gentrification dynamics. At what speed and in which manner displacement will take place (if it takes place at all) is, as history has shown, largely dependent on the future direction of local and national policies and strategies for Berlin's urban redevelopment. If this development will indeed take place—in the early 1990s, gentrification similar to Mitte and Prenzlauer Berg was expected to take place in Wedding but never materialized—the observed

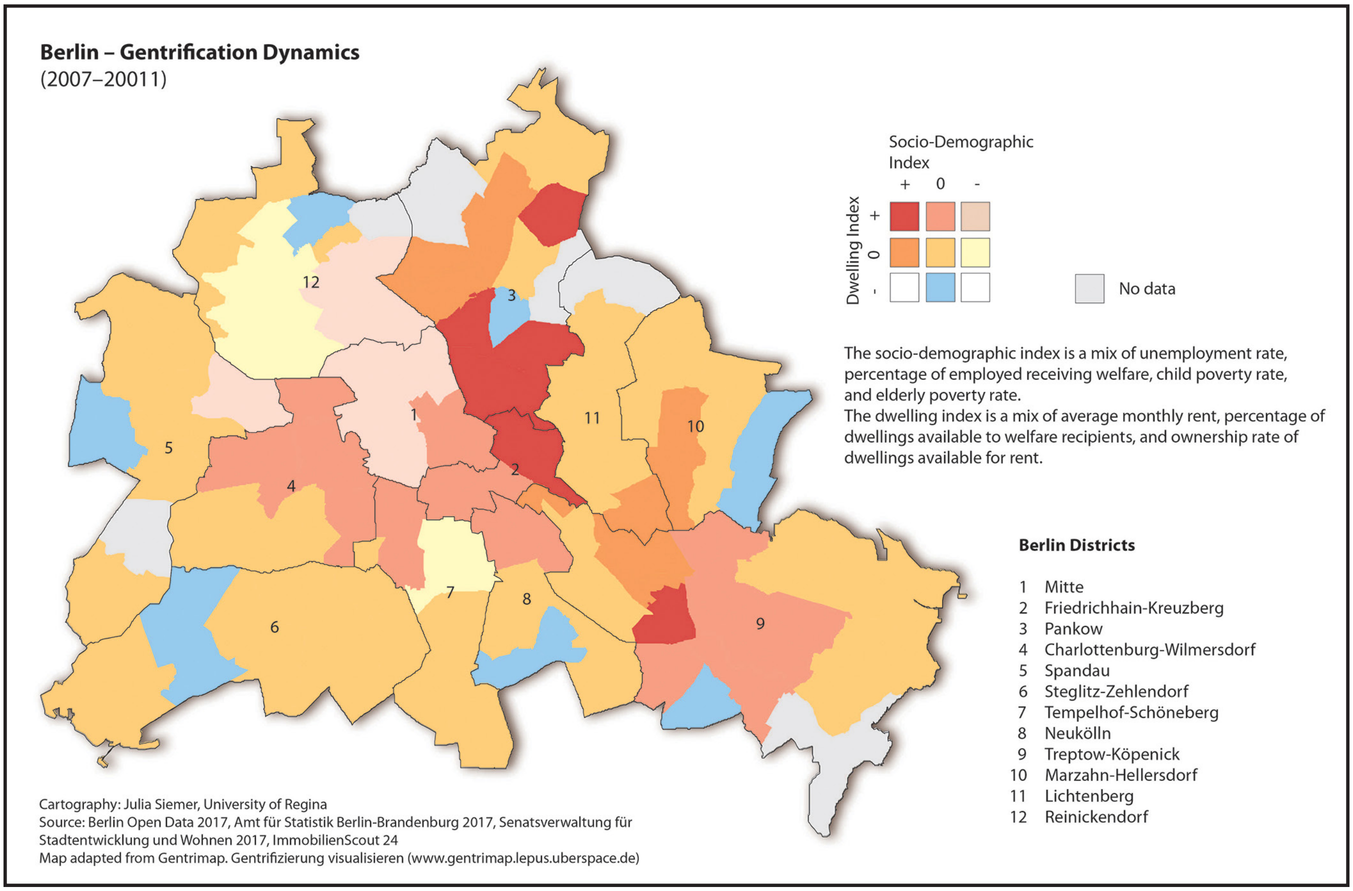

Figure 4
Potential areas for future gentrification

circular movement of gentrification will come to a full circle and possibly start a new spatial pattern of gentrification.

Conclusion

Although gentrification in Berlin has, compared to other major centres globally, started relatively late, it has developed similar characteristics and impacts for the local populations of inner city districts.

Examination of the historic backdrop of the unique situation of Berlin, controlled by two very different forms of societal and economic systems, has shown a very different development of gentrification in the two parts of the city. While reinvestment in the urban infrastructure of West Berlin took place prior to German reunification, inner city housing in East Berlin was increasingly deprived. With the fall of the Mauer, attention and capital in the inner city moved to Mitte and Prenzlauer Berg in East Berlin where the housing stock was severely neglected, and neighbourhoods in these areas became the first battlegrounds for gentrification in Berlin.

After experiencing negative impacts of gentrification, in addition to the much welcomed refurbishment of derelict housing, the influx of capital, and the development of high quality new housing, the Berlin government is now trying to lessen the impacts of gentrification on its local population. In 2016, the Senate introduced new legislation to address tourism gentrification and related short-term rentals of apartments, facilitated particularly through online services such as Airbnb (The Guardian 2016). This regulation now makes it illegal to rent entire apartments as holiday apartments on a short-term basis. First analyses indicate a slight decrease in the number of apartments offered through these services (O'Sullivan 2016). However, long-term impacts on the availability of affordable housing need to be monitored and questions on the implementation of new regulations need to be clarified.

Furthermore, the Berlin government announced in 2017 its plan to considerably increase an existing tax on second residences (Spiegel online 2017). According to this plan, the tax will be increased from currently five percent to 15 percent of the yearly rent in 2019. While this tax was not originally introduced as a measure of rent control or as an effort to curb gentrification impacts in 1998 (it was intended to generate additional income for the government) the significantly higher tax might lessen the number of individuals who want to invest in a second residence as a holiday apartment, thereby and positively influencing the availability of affordable apartments in Berlin's inner city districts.

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Prairie Perspectives: Geographical Essays

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"It's not just the food we produce, it's the community we are building": Growing healthy communities in Saskatoon, Canada

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Participation in community gardening provides multiple health-related benefits to urban residents. This case study set out to determine the perceived benefits of community gardening from the perspective of those actively engaged in urban gardening activity. This qualitative study indicates that food production, food security, environmental awareness and even healthy food consumption were perceived as secondary benefits as compared to community engagement and relationship-building. This study contributes to the body of literature that suggests urban community gardens have potential to produce more than just healthy food. Urban planners and policy makers may increasingly look to shared communal work places, such as community gardens, as places to build community capital and thus healthier urban environments.

Keywords: community gardens, community capital, Saskatoon, Canada

Introduction

Urban food production has a long and storied tradition with implications for improving human health. In Canada, urban agricultural projects have their roots in times of crisis. Urban gardens promoted food security, patriotism , and social wellbeing during World War I and II and the Great Depression (Mok et al. 2013). In the 1960s, there was an increase of urban gardening based on concerns about food related health issues, environmental conditions, rising food prices, energy conservation and ideological motivations (Lawson 2005). Since the 1980s, many urban dwellers have continued to uptake the practice of urban gardening, particularly in the form of communal or community gardens. In addition to providing local food, various authors report ancillary benefits arising from community gardening which can enhance social, health and environmental conditions (Fairholm 1999; Lawson 2005; Mok et al. 2013; Pitt 2014).

The metro-regions of Montreal, Toronto and Vancouver were forerunners in urban agricultural projects including community gardens. Today, community gardens can be found in the majority of Canadian cities (Fairholm 1999; Roseland 2012). Since 2002, the number of community gardens has grown rapidly in

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Saskatoon . The increasing demand by Saskatoon citizens for community gardens over the past decade has resulted in long wait times for new site approvals by City administration and a lack of communal space for new gardening projects. The demand for this type of communal activity has, in part, motivated this case study .

This case study examines the ways in which community gardens may offer potential for enhancing individual and community health. To conduct this research, interviews were conducted with individuals active in community gardening in Saskatoon.

Urban community gardens

Urban agriculture is defined as the growing, processing, and distribution of food and other products through intensive plant cultivation and animal husbandry in and around cities (Tornaghi 2014). The dominant form of urban agriculture is food plant cultivation (Mok et al. 2013). The most conventional practices are green roofs, roof top gardening, vertical gardens, community gardens and plots, private gardens, randomly-sited or 'guerrilla' gardens, urban agricultural projects and greenhouses (Da Silva 2009). This case study focuses exclusively on urban community gardens.

Community gardens can be defined as organized initiatives whereby sections of land are used to produce food or flowers in an urban environment for the personal and collective benefit of their members who, by virtue of their participation, share certain resources such as space, tools and water (Beilin and Hunter 2011). According to Fairholm (1999), urban community gardens have existed in Canadian municipalities since the 1890s. The history of community gardens in Canada can be explained in six overlapping periods over the last century. The 'Railway Gardens' (1890–1930) were the first community gardens in Canada (Fairholm 1999). The Canadian Pacific Railway maintained small gardens adjacent to railway stations with the purpose of encouraging prairie settlement and to improve the railway station aesthetic (Da Silva 2009). At the beginning of the twentieth century the 'School Garden' movement integrated gardening in the curriculum wherein school-aged children had a plot in which to cultivate flowers and vegetables. During the Great Depression of the 1930s, 'Relief Gardens' provided food, income and purpose to thousands of unemployed people (Mok et al. 2013). 'Victory Gardens', also known as 'War Gardens', existed during both World Wars. Victory Gardens, according to Mosby (2015) promoted patriotism and leisure while also encouraging self-sufficiency and thereby freed railcars and transport trucks to move other war-related goods across North America . Vacant lots were used for gardening during the World Wars to improve the urban aesthetic while providing food and employment for the poor. The number of community gardens declined after World War II due to supermarkets and the greater use of refrigeration. Gradually, with the emergence of the industrialized food system, food production became unnecessary for the majority of urban people (Mok et al. 2013).

The revival of urban community gardens, between 1965 and 1979, has been described as the counter-culture movement (Fairholm 1999). The renewed interest in urban gardening was based on concerns about environmental conditions, rising food prices, energy conservation, and ideological motivations against consumerism. Others feared negative health consequences due to pesticide residues in industrial food.

Since the 1980s, the demand for open community spaces has increased immensely. Research has shown the advantages of urban gardening, especially the health benefits, both therapeutic and through physical exercise (Fairholm 1999; Armstrong 2000; Pitt 2014). Mok et al. (2013) state that urban agriculture, from growing food to buying locally, has become integrated into an ideological movement of environmental and socially sustainable choices, community networks, reconnection with nature, and social change in North America. Today, the American Community Garden Association estimates that there are over 18,000 community gardens in the USA and Canada, ranging from neighbourhood gardens to public gardens and school gardens (Mok et al. 2013).

Community gardens in Saskatoon

Community gardens have become increasingly present in Saskatoon. Modjeski (2014) states that the amount of community gardens has increased by almost 79 percent from 19 in 2012 to 34 in 2014. The number of community gardeners grew by almost 52 percent from 1450 in 2012 to 2200 in 2014. The demand for community garden plots has outpaced the supply (Modjeski 2014). The first official community garden in Saskatoon, the City Park Community Garden, opened in 2002. A garden shed re-construction in 2013 drew community members together (see Figure 1). At present (2016), there are 46 community gardens in Saskatoon, which is a doubling in total number since 2012 . The intent of these gardens is public availability to the entire community, encouraging community spirit by working together and getting to know neighbours, and agreeing to food production via organic gardening principles (City of Saskatoon 2016).

In Saskatoon, gardens range in size between a dozen plot spaces and up to more than 50 plot spaces. Individual garden plots range in size from 16-25 metres square (CHEP Good Food Inc. 2016). Over half of the community gardens are located on municipal land. Others are placed on private, school or church property. To date, the City of Saskatoon has supported the implementation of more than 20 community gardens on City-owned land in collaboration with CHEP Good Food Inc. (formerly Child Hunger Education Program). CHEP is a non-profit organization working with children, families and communities to improve access to good food and promote food security (CHEP Good Food Inc. 2016). CHEP supports community gardens on private, school or church property as well.

Method

The objective of this study was to determine the perceived benefits both to the individual and community arising from com-


Figure 1
City Park Community Garden
Source: http://www.openprojects.ca/2014/11/19/city-park-community-garden-shed-build/

munity gardening. As such, we developed an interview guide to be used in the field with key individuals. Key individuals were selected based on their activity in community gardening in Saskatoon. The 'snowball method' added additional individuals to the interview pool. Potential interviewees, with different ages, occupations and backgrounds were chosen to be interviewed. In total, nine individuals with expertise in and knowledge of community gardening in Saskatoon were interviewed. The number of interviewees was less important than the quality of those interviewed. Interviewees were highly committed community gardeners who fulfilled an essential role in their community gardens. All interviewees were community coordinators or volunteers that were responsible for several tasks in the community garden movement in Saskatoon. The interviewees represented a broad range of adult age groups including a university student.

Results

The interview questions sought to identify perceived benefits from community gardens. Questions did not prioritize community over individual benefits nor did the questions identify potential motivating factors such as healthy food production or active living. Open-ended, semi-structured questions were asked to tease out perceived benefits of community gardening.

Food Security

Local food production has long been held as rationale for urban agriculture. City of Saskatoon promotion of community gardening cites "growing nutritious food" and to "support food security" as a motivating factor for local uptake (City of Saskatoon 2016).

All interviewees confirmed that community gardens can contribute to food security. However, one interviewee stated that only a small fraction of community gardeners actually engages in this activity to become more food secure. Another interviewee noted that for some gardeners living on a fixed, limited budget, food security is important: "Since healthy food is usually pricier than processed food, growing their own food allows the poorer inhabitants to consume better quality produce." In a winter city such as Saskatoon, there is an additional limitation to food security. In the words of one interviewee: "Community gardens do impact food security but on a small scale because of the short growing season [in Saskatoon]. For those growing months you have access to fresh produce." Another interviewee stated that not all gardeners have sufficient knowledge to grow their own food: "… in some cases, people do not possess sufficient knowledge about gardening which can reduce their motivations to garden. Therefore, it is fundamentally important to support people and show the potential achievements of gardening. Community gardening would not be the only solution [to ease food insecurity] but it can contribute to food security for sure."

Diet Outcomes

All interviewees reported the valuable contribution of fresh, local, organic, nutritional and flavourful fruits and vegetables to their diet. How food is grown and its origin were important criteria for the interviewees: "… we know that it is local and it is organic and that it is not sprayed with pesticides and shipped around the world and losing nutrients every day. When we pick it we eat it that day the whole summer. Besides, vegetables in stores might look good but they do not taste as good or fresh as self-grown produce." Moreover, there is an additional cultural consideration to local food production. As one interviewee stated: "Community gardens provide the opportunity for immigrants to grow certain plants, herbs or vegetables which they have been used to eating their entire lives."

Environmental awareness

All interviewees indicated that they compost at the community garden and at home. Some interviewees intend to be role models for other people: "My motivations are to build a more sustainable community here in Saskatoon in the long term and to have quality food all the time…while helping people to make a better impact on the planet." All interviewees indicated that community gardens have the potential to improve the environmental awareness of the gardeners. Interviewees predicated that community gardens are a source of education for gardeners to gain more knowledge about food production and relating issues. Growing produce organically is a major aspect of community gardening and a requirement of the City's community garden policy. Interviewees demonstrated that they see community gardens as a platform to communicate environmental issues and to get exposure to new environmental practices. In the words of one interviewee: "… people [community gardeners] are conscious about the environmental footprint . They are seeing the connection of the activities and lifestyle changes that reduce the footprint on the earth." In this case, "Community gardening gives the people a common purpose and a place to talk about mutual concerns." Still others reported that community gardeners get exposed to sustainable practices and ideas they have not thought about before such as composting, commuting by bicycle, or purchasing only organic produce at the grocery store. Additionally, one interviewee reported their participation in community supported agricultural (CSA) programs, stating that: "[i]n a CSA, individuals who have pledged to support one or more local farms pay at the onset of the growing season for a share of the anticipated harvest. In this way, participants support local agricultural businesses, eat seasonal produce and know where and how their food is produced." Across all interviews it was stated that through community gardening there was increased exposure to environmental issues and practices and a general sharing of ideas. As one interviewee stated:

> "I think it is a good way for people who want to learn more [about the environment] because they see the value…this may lead them to seek more information regarding other sustainable practices. I think it does have a potential, not like 'I community garden so I care about the environment' but 'I personally like community gardening and I care more about these things because I got exposed to them.' So I think it is just a gateway not a path."

Physical activity and mental health outcomes

All interviewees agreed that community gardening can be beneficial for physical activity and mental health: "It is good physical exercise because you are shovelling, pulling things and bending down to weed, especially for seniors gardening can be good exercise." Interviewees stated that mental health advantages can occur thanks to the relaxed atmosphere in community garden sites. Interviewees see gardening as a joyful activity in fresh air which helps to reduce stress. According to an interviewee: "…it [community gardening] could be seen as a therapeutic activity. In addition, gardening can help to build self-esteem and experience gratification towards one's own work." Other interviewees experienced transformational change as they learned to appreciate nature with the great amount of produce grown on a relatively small plot. Moreover, several interviewees noted that gardening can improve the sense of safety in the neighbourhood based on an extended social network. Conversely, some interviewees declared that community gardening can also be mentally challenging due to stress or disappointment. Vandalism, theft, threat of frost, spoiled food, preserving the harvest, and the lack of engagement of other gardeners were reported to be negative influences on community gardening. It was reported that in some instances gardeners became inactive in community gardens because of negative experiences.

Outcomes related to social relationships and community involvement

The interviewees ranked the importance of social aspects and community involvement very highly. The communal aspect of community gardens was one of the biggest advantages of community gardening for all interviewees. Community gardening expanded the social network of community gardeners by meeting people with diverse backgrounds The garden network brought together the young and elderly, ethnic diversity, immigrants , renters and homeowners as well as mixed gender. As stated by one interviewee: "… community gardening is a good way to get in touch and be involved in the broader community especially for newcomers in the neighbourhood." Another gardener noted: "I like meeting neighbours. I like connecting to people. I like to have a more intimate relationship with my neighbours that makes you feel safer and that makes you feel happier. So I garden."

Interviewees stated that there is a lot of sharing of actual food, recipes, seeds, tools but also ideas and knowledge among community garden members. A number of interviewees noted that the social interaction and communication about food can enhance community cohesion as well as intercultural communication and integration processes. According to a community gardener: "Community gardening forces people to communicate. In the case of a beetle infestation or the maintenance of the collective spaces, people have to talk to each other in order to find solutions. It is a community building activity and it really brings people together." Interviewees indicated that the social events happening in the community gardens are very diverse. Gardens usually have work bees, which are work inputs and potlucks during the season - others have a "Weeding Wednesday" once a week.

In one community garden, people just bring their coffee and sit down at the picnic tables and chat. At the University of Saskatchewan, the community garden offers canning and weeding workshops and a variety of cultural programs. At another community garden a live music event is organized every second Wednesday with local musicians. Additionally, CHEP organizes community garden conferences in winter allowing gardeners to connect with people from all over the city. Moreover, interviewees reported that people build relationships through gardening which can go much further than the garden. “You get attached to the people and to the atmosphere. It is more than getting food. You show up to get food just as an excuse to see people almost… it becomes more about sharing personal things.” People can start to develop neighbourly relationships which can include meetings outside the garden site. Another important aspect is the opportunity to get engaged in the community beyond community gardening. In the words of a community gardener: “When you have a potluck…You start to have this conversation about work that needs to be done in your neighbourhood or other volunteer opportunities or other committees that are looking for help. It really takes people who like to get involved and gets them involved in more things.”

Interviewees also reported there are some gardeners who do not invest much time in the community. They just garden their own plot and are generally more motivated to look after their own belongings than to look after common property.

Discussion

The main findings of this article identify five perceived benefits arising from community gardening. These comprise: food security, diet outcomes, environmental awareness, physical activity including mental health, and social relationships including community interaction. While all these benefits may be linked directly and indirectly to human health it was social relationships rather than food production that was reported to be the strongest perceived benefit of community gardening. The results of this case study will now be discussed in light of current literature.

These findings indicate that the social aspect of community gardening is the main benefit of community gardens as perceived by the gardeners. This result was somewhat surprising in view of the attention given to urban food security (Roseland 2012). The social aspects of community gardening serve to enhance a sense of well-being within a neighbourhood, which augments the quality of life for the individual. The supply of fresh fruits and vegetables is important but associated cost savings at the supermarket are not the uttermost priority for the interviewees. The fact that social networking is the biggest driver of people engaging in community gardens is linked to the connection of place between people of similar interest. Meeting people with other backgrounds might also diversify one’s interest and knowledge about a variety of topics. Studies identify the social benefits of community gardens in industrialized countries. Eigenbrod and Gruda (2015) note the social and educational benefits of community gardens strengthen the gardener’s community. Research demonstrates that community involvement and engagement strengthens the social networks of community gardeners which contribute to an enhanced sense of quality of life (Lovell et al. 2014). Studies also show that personal motivations differ. Therefore, access to fresh fruits and vegetables, environmental stewardship or improved personal health can also be motivating factors (Drake and Lawson 2015). For instance, gardeners in low-income neighbourhoods usually start gardening to cost efficiently produce their own food (Armstrong 2000).

In this case study, interviewees noted that a major advantage of self-grown fruits and vegetables is the assurance that the produce has been produced sustainably without any chemical treatments. The consumption of local produce leads to ‘peace of conscience’ because gardeners feel certain about the freshness and nutritional value of the produce. Moreover, the opportunity to grow different plants creates a feeling of resistance against the uniformity of industrially produced fruits and vegetables. Different types of the same produce contribute to a diverse diet. According to other studies, gardeners value the nutritional input of self-grown fruits and vegetables very highly (Lovell et al. 2014).

Interviewees affirmed positive physical and mental health outcomes thanks to community gardening. For all interviewees, gardening is a hobby which they do for fun with great passion while socializing at the same time. Therefore, it is not surprising that community gardening influenced their mental health positively. The work required to cultivate a community garden often increases the physical activity of people, which can be beneficial for overall health, especially for seniors who might not get enough exercise otherwise. A major increase in physical activity among respondents was not identified, but rather, a small, more leisurely increase of physical activity. In addition, community gardens strengthened the mental health of gardeners thanks to the relaxing atmosphere which reduces stress. Gardening also produced a feeling of achievement and gratification among interviewees that further enhanced the mental health of the gardeners. However, in some instances gardeners noted increased stress as a result of vandalism, theft or other problems which negatively impacted their mental health. Those interviewees who accept these petty crimes as a part of community gardening seem to manage negative experiences much better. Similarly, the literature links gardening to enjoyment, mental restoration, stress recovery and improved neighbourly connections which improve the mental health of gardeners (Pitt 2014). Gardening is known to be a moderate to intense physical activity with the potential to improve health data such as cholesterol and blood pressure levels (Armstrong 2000). Other studies identified community gardens as shared communal spaces, or third places (Roseland 2012), where social gathering can be a therapeutic activity that positively influences mental health (Lovell et al. 2014).

Studies confirm the role of community gardens to mitigate food poverty through financial savings (Lovell et al. 2014). It is difficult to quantify the savings because the produce is usually not weighed in the gardens. Therefore, financial savings cannot be accurately calculated from this case study making it difficult to compare product cost of the community garden with conventionally produced fruits and vegetables. Other studies also referred to the accessibility of fresh produce. Community gardens offer a convenient way to access fresh fruits and vegetables, particularly for the population with limited access to supermarkets due to distance and high transportation costs (Alaimo et al. 2010). In Saskatoon, 55 percent of the citizens do not live within walking distance (one kilometre) of supermarkets (Kouri

2013). Residents in certain neighbourhoods live closer to fast food stores than to supermarkets, limiting their access to fresh produce. This condition is exacerbated in lower socio-economic neighbourhoods where public transportation options are limited and rates of car ownership are low (Patrick and Cheesbrough 2012). According to Mok et al. (2013), community gardens influence food security through improved accessibility to and affordability of fresh produce. Due to time and resource constraints, this case study concentrated in part on the financial savings potential of community gardens to address food insecurity. The mitigation of food insecurity among community gardeners cannot be identified directly based on the selection of interviewees as none of the respondents were food insecure.

Studies identify community gardens as a model for the promotion of sustainable urban living (Turner 2011). For the majority of interviewees in this study, environmental reasons were one motivation to engage in community gardening. Still, the case study and literature findings show that even though people commit to growing their own food and caring about the environment, they do not necessarily change their behaviour in other aspects of their life (Turner 2011). Studies about environmental awareness and behaviour demonstrate that both factors do not necessarily correlate. There are many reasons why people do not act more in line with their environmental convictions, such as increased costs, personal habits, routine and personal interests. The case study identified that in one community garden only one third of the gardeners walk to the garden, while others still drive.

The integration of community gardens into urban neighbourhoods can create healthy, civilizing and enriching places to live by improving all forms of community capital including not only natural and economic capital but also social, cultural and human capital (Roseland 2012). Based on this study, community gardens offer great potential as catalysts to build, maintain, and enhance community capital by mobilizing citizens and governments around a common, collective activity. The importance of community gardens has a far greater reach than local food production. For this reason, the mental health benefit to those active in community gardening should not be overlooked. The integration of health and place, at least in the urban environment, may begin in the community garden.

Conclusion

Since 2002, when Saskatoon's first community garden was created, there has been increasing interest in community garden space in the city. By 2016, there were 41community gardens and the implementation of five to ten community gardens per year was common.

Multiple impacts of community gardens on gardeners, communities and cities have been identified in the literature. The positive effect of community gardens is evident in Saskatoon and significantly increases the community capital of the city particularly by growing social networks and improving community cohesion. Moreover, enhanced physical and mental health from physical activity, nutritious diets and mental rest contribute to human capital. Increased food security among community gardeners positively affects economic capital since financial assets can be spent on other goods. Mental and physical health are improved by reducing stress and nutritional imbalance caused by food insecurity. Greater environmental awareness influences physical and natural capital by promoting good quality food as well as vegetated 'green' spaces and other sustainable practices which enhance the condition of the natural environment of the city.

Overall, this case study identifies community gardening as a highly beneficial activity with positive benefits to the gardeners, broader community, and Saskatoon in general. Therefore, the promotion of community garden participation in Saskatoon, and elsewhere, is highly recommended. The City of Saskatoon is encouraged to look for new communal space for community gardens. Under-utilized public and private spaces, including vacant public property, should be considered to meet the increasing demand for community garden space.

Community gardens alone cannot create healthy cities. However, they are a relatively small scale activity with potential to contribute to healthy urban places.

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Prairie Perspectives: Geographical Essays

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Canadian Association of Geographers
Association Canadienne des Géographes

Field trip: Ukrainian and Jewish settlements northeast of Melfort, Saskatchewan

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Context

Melfort is a small town of some 6000 people in Saskatchewan's Carrot River Valley. This field trip focuses on the area's settlement history and the town's attempts to preserve and commemorate its agricultural and civic heritage. The settlement was established as a station stop on the Canadian Northern railway in 1904 and given the name Melfort by one of the settlers in honour of her birthplace in Scotland. It grew slowly as a regional administrative and agricultural centre servicing surrounding farms. In the early 1900s, the area to the northeast of Melfort was settled by groups of Ukrainian and Jewish settlers. English-speaking and German settlers were also a part of the area's ethnic mix. This field trip concentrates on that culturally heterogeneous area. It is comprised of a road tour of historic country churches in the region, a walking tour of the historic downtown, including a visit to the post office (1912), and an indoor tour of the impressive Melfort and District Museum.

Country churches road tour

The road trip explores the area northeast of Melfort to illustrate the impress of various groups on the landscape through their religious and cultural institutions. The route is shown in Figure 1. All distances given are approximate. Leave Melfort via Broadway Avenue heading north on Highway 6 towards Gronlid. After 19 km (12 mi) Highway 6 veers east. Travel 5 km (3 mi) further until Highway 6 veers north, then turn right and continue east to Maryville. At Maryville, St. Nicholas Ukrainian Catholic Church and the Ukrainian Orthodox Church of the Holy Ascension are to the north and south of the intersection respectively. Turn right and proceed south. About 0.8 km (0.5 mi) south, St Helen's Polish Roman Catholic Church is on the right. Continue 2.4 km (1.5 mi) south. At the T junction (the correction line) turn left, and head east for 5.6 km (3.5 mi) to Highway 681. At Highway 681, turn left, head north for 5 km (3 mi). Shortly after crossing the bridge over the Carrot River, a small building on the west side of the road is the Beth Israel Synagogue. A vehicle track provides access to the adjacent Jewish cemetery. Leaving Beth Israel, continue north until the intersection of Highway 681 with Highway 335. Turn left, heading west. 1.6 km (1 mi) to the west, St Michael's Ukrainian Catholic Church stands on the south side of the highway. Continue to Gronlid via Highway 335. At Gronlid, turn left and proceed south to Melfort on Highway 6.

Slavic and German settlement

As the route begins proceeding north on Highway 6, shortly before the turnoff to Levendale, on the west side of the highway, just before it crosses Melfort Creek, is the site of the Melfort Lutheran Church. Although the church building has long since van-

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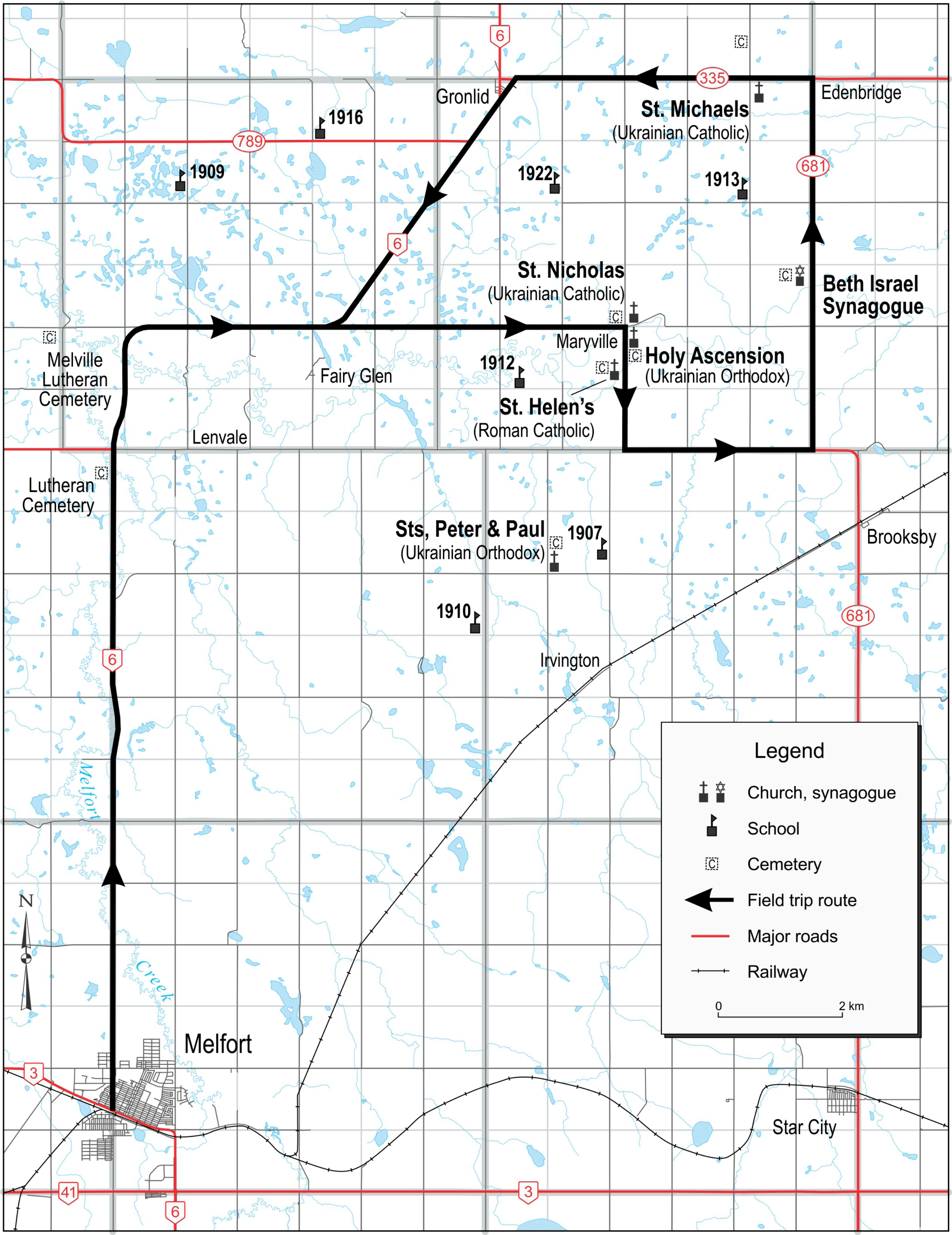

Figure 1
Field trip route map
Map Credit: John C. Lehr and Weldon Hiebert
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ished, a cemetery immediately south of the creek remains from the initial settlement of this area by German Lutherans. North and east of this point the land was settled principally by Ukrainian settlers, mainly from Zalyshchycky and Zbarazh counties of the then-Austrian province of Galicia. They were attracted to the region by the availability of free homestead land and the environmental attributes of the area. Most Ukrainian immigrants had little capital when they arrived in western Canada and were unable to contemplate immediate entry into commercial farming. Their immediate concern was survival, which meant entry into a semi-subsistence mixed farming economy, which in turn demanded easy access to wood for fuel, fencing and building, water for stock, and prairie openings for grazing. This area was thus one that met their environmental needs and had the added attraction that off-farm employment was available in nearby lumbering camps and with earlier-arrived German-speaking settlers.

Little remains of the once-distinctive Ukrainian cultural landscape. Until the 1970s, traditional-style Ukrainian log buildings were a common feature of the rural landscape, but depopulation and farm consolidation coupled with modernization erased them from the landscape. The few that remain are abandoned and in sad disrepair. Yet the Ukrainian presence is still clearly visible in the landscape through the numerous churches, cemeteries, and National Homes (Community Halls) in the area. This field trip passes by several churches that were built in the colonial settlement era by local craftsmen and still survive, albeit precariously. As rural populations decline, congregations shrink in turn, leaving ever fewer people to maintain religious life. Rural churches become served by priests on an irregular basis and are used mostly for weddings and funerals. Cemeteries fare better but grow neglected as the area's population disperses into the larger cities of western Canada and beyond.

A cluster of churches near Maryville illustrates the significance of religion in the resettlement era. For many immigrants, religious affiliation defined identity more accurately than their official nationality. For instance, those who came from the Austro-Hungarian province of Galicia, being Greek Catholic defined one as Ukrainian, whereas observers of the Roman Catholics faith were seen as Polish. Members of the Greek Orthodox Church were invariably Ukrainians from Bukovyna, at least until the early 1920s, when a surge of new-found Ukrainian nationalism and reluctance to cede local control of church property to Rome, caused many Greek Catholics to switch their allegiance to Orthodoxy.

The origins of the Ukrainian Catholic Church demand some explanation. Whereas Christianity spread into Poland from Rome, it spread into Ukraine and Russia from the Greek city of Byzantium (Constantinople). Thus, while Roman Catholic missionaries to Poland took with them the Roman alphabet, Greek Orthodox missionaries from Byzantium spread the Greek alphabet for the Slavic languages adapted by St. Cyril. Thus, Poles use the Latin alphabet, but Ukrainians use Cyrillic, a division that is seen in the tombstone inscriptions in cemeteries and church signage at sites visited on this field tour. To bring Greek Orthodox Ukrainians in Galicia into the fold, the Roman Catholic hierarchy established the Greek Catholic church in 1596. This new church kept the Slavic liturgy and the tradition of secular (i.e., married) priests, but acknowledged the Pope in Rome as its spiritual head. The church became dominant in Polish-controlled Galicia but not in those areas of Ukraine where the Catholic Poles lacked political influence. Within the settler community, adherence to Greek Catholicism carried inferences of Polish influence. Conversely, the Orthodox were suspected of Russophile leanings. Religious friction which carried political undertones, remained a feature of life in Ukrainian rural communities for decades.

The presence of Roman Catholic, Ukrainian Catholic, and Ukrainian Orthodox churches shows that the Slavic settler community was divided among Polish Roman Catholics and Ukrainian members of the Greek Catholic and Greek Orthodox Churches. Ukrainian-Catholic and Ukrainian-Orthodox are easily recognizable through their design which features the distinctive Byzantine domes, a tripartite floor plan and a separate bell tower. Whereas Ukrainian-Catholic churches usually have their dome surmounted by the simple Latin cross, Orthodox churches generally have a cross that has three horizontal crossbeams with the lower beam slanted to the right. Polish Roman Catholic churches were very different in appearance. Most feature a tower and spire, which may house a bell; they lack any trace of Byzantine heritage which is so prominent in the design of Ukrainian churches, whether Catholic or Orthodox.

There are several churches to visit on the tour route. At Maryville, there are three within 1 km (0.6 mi). Approaching from the west, St. Nicholas' Ukrainian Catholic Church lies ahead to the left on SW15-47-17 W2. The church was built in 1912 and has a tower that houses three bells. A parish hall was built adjacent to the church, as was a barn capable of accommodating 50 horses. South of St. Nicholas' Church the now abandoned Ukrainian Orthodox Church of the Holy Ascension and the Taras Shevchenko Hall, which served the community's cultural needs for many years, are located on NW 10-47-17 W2. About 1 km (0.6 mi)south, on NE 9-47-17 W2, St. Helen's Polish Roman Catholic Church and its adjoining cemetery, lie on the west side of the road.

Jewish settlement: Edenbridge

Following a series of bloody pogroms in eastern Europe in the 1880s, thousands of Jews fled Europe for North America. Most went to the large cities of the United States eastern seaboard; others went to urban destinations in eastern Canada. Various philosophies influenced the behaviour of these Jewish refugees, including a belief that to become a part of a nation it was imperative to develop a bond with the soil. The belief held that this could only be achieved by physically working the earth itself, in other words, by becoming agricultural pioneers. This 'back to the land' philosophy underpinned early Jewish efforts to establish farm colonies in western Canada. Notably, some of the earliest agricultural settlements in Saskatchewan were established in the 1880s by Jewish pioneers. Most did not fare well partly due to environmental adversity and partly because tenets within Judaism make it a religion that thrives best in large nucleated communities.

For a Jewish settler to remain religiously observant while living on a homestead was extremely difficult. Their religion requires them to gather on the Sabbath to read the Torah but also requires a quorum of ten adult males for this to occur. The rules also state it is forbidden to venture more than a mile (1.6 km) from one's residence, and that one is only permitted to walk. Riding a horse or driving a vehicle is strictly forbidden. Jews are also required to observe the rules of kashrut— to eat only kosher meats slaughtered by a shochet— and to observe a host of other rules. These are easily obeyed within the confines of a large nucleated community but are extremely difficult to adhere to when living on homesteads scattered across a wide swath of territory.

The Jewish farm colony of Edenbridge was established in 1906 by a group of Jewish settlers from Lithuania who arrived in Canada after spending some years in South Africa. They were met by others who came via London, England, and via New York. The name Edenbridge appealed to the early settlers who thought it derived from Yid'n bridge, translating to the Jews' bridge in Yiddish. Most settlers of the Edenbridge colony acquired their land by homesteading; only a few had the means to purchase land. Jewish settlers in western Canada received limited financial aid in the form of loans from the Jewish Colonization Agency (JCA). The JCA was headquartered in Montreal and was often regarded as being out of touch with the financial realities of pioneer settlement in western Canada, offering insufficient aid and doling it out in a parsimonious fashion.

Like most other Jewish colonies on the prairies, Edenbridge sprawled over several townships. As a result, it never achieved the high degree of nucleation required for the observance of religious rules. Moreover, Jews often settled among already-established Gentile settlers, so maintaining a truly observant Jewish religious life was difficult. In the immediate vicinity of Edenbridge they achieved some measure of concentration, as the map in Figure 1 illustrates. Nevertheless, Gentile settlers and their Christian institutions were to be found within the area where Jews were most closely congregated. Although over 80 Jewish families settled in Edenbridge at one time or another, like many other Jewish colonies, Edenbridge was marked by fluidity. Settlers came as others left, so the numbers of Jewish families residing in Edenbridge at any one time was never as large as the numbers immigrating might suggest. According to JCA reports, 1910–1911 saw the greatest number of arrivals, when some 32 families arrived. In 1912, six more families came, followed by three in 1913. Only four more families arrived over the next ten years.

At its peak, the Edenbridge colony had a population of about 170 people with a school, post office, store, and synagogue. Whereas the school and synagogue were spatially stable, the post office location moved as the postmaster changed. From its establishment until 1917, the office was in David Vickar's store on NE25-47-17 W2 (Figure 1). Today the only remaining tangible evidence of Jewish presence in the area is the Beth Israel Synagogue (Figure 2) and the adjacent Jewish cemetery. The synagogue was built in 1906 and is now a designated Municipal Heritage Site of the Rural Municipality of Willow Creek. It has a wooden frame exterior, steeply pitched roof and lancet windows that typify the 'Carpenter Gothic' style buildings erected by many religious groups across North America. The synagogue is no longer used for religious services.

A few metres from the synagogue, a short vehicle-accessible trail leads to the Jewish cemetery west of the synagogue (Figure 3). Tombstone inscriptions are in Hebrew and, on the more recent headstones, in English.

Figure 2
Beth Israel Synagogue
Photo credit: Weldon Hiebert

Figure 3
Jewish cemetery adjacent to Beth Israel Synagogue
Photo credit: Weldon Hiebert

Walking tour of Historic Melfort

Like many other cities, Melfort struggles to retain its built heritage. The Historic Post Office, located at 302 Main Street serves as an illustration of the town's rich architectural past and the questions it faces in preserving these buildings for the future. Built in 1912, is an imposing Romanesque revival-style building on a prominent corner at the intersection of McLeod Avenue East and Main Street. At various times the building also housed Canada Customs and Revenue on the second floor, RCMP detachment offices and officers' accommodation. The Department of National Defense at one time used the basement as an armory and gun range. The building is no longer used by any federal agency and no permanent alternative use has been found. A building assessment and feasibility study conducted in 2012 found the building to be structurally sound, but recommended a conservation/stabilization program be undertaken immediately to slow the rate of deterioration, pending a complete restoration. It is one of the few remaining early-twentieth century public buildings in Saskatchewan that symbolize the federal government's presence in small communities. Its design and vast size demonstrate the high hopes and optimism of the city's early years. Designated a Municipal Heritage Property in 2012, it is used on an occasional basis for community events.

Melfort and District Museum

The Melfort and District Museum showcases a pioneer-era village of 18 buildings, including machinery shops, a sawmill, exhibit hall, and power house. The pioneer village commemorates the city's past very effectively, using original buildings to replicate a street from the colonial settlement era. Other buildings include a grist mill, blacksmith shop, post office, doctor's and dentist's offices, the Rathwell School, St. Paul's Anglican Church, and a general store. The site also offers vintage farm machinery, equipment, and tools.

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