strategically important, threatened or scarce (Bunker and Houston, 2003). However, the post-war growth of all the major Australian cities pushed peri-urban fringes further from city centres, creating characteristic low-density urban development, often described as urban sprawl (Costley, 2006; Glackin, 2013; Gleeson, 2008). Thus, managing growth in the peri-urban fringe has been a key element in the planning of Australian cities while also being of major concern for current academic study. This is illustrated by Kennedy et al. (2016) and two recent major conferences at the universities of La Trobe and Western Sydney respectively on the themes of 'beyond the edge' (http://www.latrobe.edu.au/periurban) and 'peri-urban futures' (http://www.periurbanfutures.com/index.php/events/international-conference-on-peri-urban-landscapes). Because the fringes are under a degree of planning control that is rare in the United States (US), rates of peri-urban growth in Australia have been much lower than in the US (Bunker and Houston, 2003). Nevertheless, evidence suggests that for many decades peri-urban areas have been the fastest-growing regions in the nation (Maher and Stimson, 1994; McKenzie, 1996), stimulating further investment in dwelling construction (Buxton et al., 2007; O'Connor and Stimson, 1996). If this growth trend continues, land lost to new development may compromise high quality agricultural land, water conservation, and 'green' space for preservation and recreation in the fringe.

Given this background, this study focused on peri-urban residential development, specifically in an Australian context, using Adelaide, the capital of the state of South Australia, as a case study. It builds on recent work on planning for the Greater Adelaide region (Kellett, 2014; Mahmoudi et al., 2013; Robinson and Liu, 2015; Sivam et al., 2012). This shows Adelaide presents distinctive patterns of spatial growth and planning history, including several key initiatives spanning several decades (e.g. ACC, 2012; DEPSA, 1992; DPTISA, 2010; South Australia's Strategic Plan Update Team, 2007; Town Planning Committee, 1962). These initiatives provide useful reference points that will inform the analysis herewith. Exploring the processes and change mechanisms associated with residential development in peri-urban fringes is crucial to develop more appropriate planning and policy responses. This paper thus reports on an exploratory analysis using various techniques, including variation partitioning, to investigate selected and conceptually important drivers of observed patterns of spatial development and the relative importance of different groups of forces.

The broader context for this research is an Australian planning system in which the planning of the larger metropolitan areas is largely in the hands of state governments. State strategic plans broadly seek to ensure an adequate and affordable supply of land to accommodate private and commercial purposes, to maximize accessibility of jobs and services to the regional population and minimize aggregate travel, whilst minimizing impacts that urban consumption and production activities have on the environment (Murphy, 2007). Urban suitability studies accompanying the plans generally distinguish three types of fringe development: incremental (at numerous points), linear sectors (generally related to major highways and/or suburban train routes) and satellite towns. All of these can include coalescence with existing settlements so that metropolitan planning involves several local government areas and the need for high levels of co-operation and co-ordination between agencies under different jurisdictions (Bunker, 2012; Gleeson et al., 2004). Preservation of high quality agricultural land plus 'green' space for conservation and recreation are other important considerations. Once plans have been formulated greenfield sites can be released for development and included in detailed land-use plans leading to land developers commencing sub-division and building houses.

Metropolitan strategic planning in Australia favoured suburbanization in the first thirty years after World War Two. However, from the 1980s onwards there have been moves promoting 'densification' and 'urban consolidation' or higher residential densities within major cities, thereby restricting rapid urban expansion and new development in peri-urban fringes (Beattie and Haarhoff, 2014; Randolph, 2006; Ruming, 2014; Troy, 1996). This trend has been associated with urban renewal projects, notably in Brisbane, Melbourne and Sydney, and greater concentration of commercial development and public services (Chhetri et al., 2013; Ganis et al., 2014; Searle, 2013). In terms of analyzing new developments in peri-urban fringes, there is an opportunity to consider measurable influences on the location of new housing alongside the implementation of the strategic plans that underpin the location and direction of new growth.

1.2. The forces shaping the location of peri-urban residential development

Residential development in peri-urban fringes may be affected by many drivers, such as population growth, socio-economic and cultural development (Heimlich and Anderson, 2001; Low Choy and Sutherland, 2008), environmental and geographical factors (Mann et al., 2014), and spatial planning and development policies (Low Choy et al., 2007). Recently, a paradigm for the driving forces underlying human settlement has been proposed depicting three stages, characterised by natural resource constraints, expansion of the transport system, and the attraction of natural amenities (Gude et al., 2006; Huston, 2005; James, 1995; Riebsame et al., 1996). According to this paradigm, peri-urban residential development is also associated with these three types of factors, but this has received little empirical testing.

Recognizing the effects of driving forces on peri-urban residential development from global and local perspectives is an important step in understanding the change mechanisms of this development. It is possible to calculate the global influences of some forces by employing statistical methods, such as interactions-based models (Irwin and Bockstael, 2002), probit models (Carrión-Flores and Irwin, 2004), logistic regression (LR) models (Liu et al., 2015; Newburn and Berck, 2006) and spatial panel econometrics (Mann et al., 2014). Among these methods, LR models have been widely used because they possess high explanatory power (Gobin et al., 2002). Geographically weighted regression (GWR) is a relatively simple and effective tool for examining spatial variation in relationships between explanatory variables and response variables from a local perspective (Gao and Li, 2011). It has been recommended for use in conjunction with global models (Ogneva-Himmelberger et al., 2009), such as LR models, although the common occurrence of multi-collinearity and spatial autocorrelation (Griffith, 2008; Robinson, 1998; Wheeler and Tiefelsdorf, 2005) can restrict its application.

The relative importance of broad factors (Peres-Neto et al., 2006) underlying peri-urban residential development is vital to help develop policy response. Yet there have been relatively few analyses evaluating it because of complex interactions of various forces. One example is the work of Gude et al. (2006) who built univariate generalized linear models and multivariate statistical models to explore the relative contribution of various forces to rural residential development in the Greater Yellowstone area, Montana. Although using generalized linear models may be an effective way to assess the relative importance of various forces, it provided insufficient information about their contributions to changes in residential development. Variation partitioning has proven a useful and simpler method to measure the relative importance of explanatory variables to response variables. For example, Li et al. (2013) employed variation partitioning to explore the relative contribution of physical, socio-economic and neighbourhood factors to urban expansion. Given this background, this study seeks to

measure the relative importance of different groups of forces on peri-urban residential development by using variation partitioning.

We determined spatial patterns of residential development for four ten-year periods from 1971 to 2010 using parcel-level data, starting in the 1970s to reflect the boom in residential development occurring at that time in Adelaide's peri-urban fringe, where close to 74% of the existing housing stock has been built after 1970.

Considering the aforementioned paradigm of human settlement, and building on the prior work by Gude et al. (2006), we mainly focused on three sets of factors underlying peri-urban residential development: the road network and associated services, natural amenities, and previous residential development. The present study applied LR and GWLR models to quantify the individual effects of selected variables on new residential development globally and locally, respectively. Furthermore, it used variation partitioning to test the pure and joint contributions of the three categories of forces to new housing development in peri-urban fringes.

The specific objectives of this study were:

- to explore how the impacts of spatial determinants on peri-urban residential development varied over time and across space;
- to evaluate the relative importance of three groups of spatial determinants to peri-urban residential development;
- to consider the policy implications of the results.

2. Method

2.1. Study area

With a population of approximately 1.31 million (ABS, 2011), Adelaide is the capital and the financial, political and commercial heart of the state of South Australia. It possesses significant manufacturing industries including defence, light engineering and food processing, and a wide range of business, administrative, cultural and educational services (DPLG, 2009). The city is located on the Adelaide Plains to the east of the Gulf of St Vincent (Fig. 1). The built-up area stretches 90 km from north to south and up to 20 km from the coast eastwards to a physical barrier presented by the Adelaide Hills and Mount Lofty ranges.

In the three decades between 1960 and 1990, Adelaide's built-up area grew by a factor of 3.5, from 227.4 km^2 to 801.4 km^2 (Robinson and Liu, 2015). After 1990 the rate of expansion has slowed, but the built-up area grew by 72% to reach 1375.6 km^2 in 2014. This effectively spread low-density urban development through the Adelaide Plain and beyond, with expansion in some areas of the city's rural hinterland where a considerable amount of land is being rapidly developed (e.g. at Mount Barker, Gawler and on the Fleurieu Peninsula).

Pre-World War Two there were few formal planning controls, except under the limited powers of the state's Building Act, 1923 and the Town Planning Act, 1929. Broad state interests held sway over the powers of local government with respect to regulating the location of industry and determining the calibre of public housing. New planning laws were introduced in 1962 (Marsden, 2004), with the *Report on the Metropolitan Area of Adelaide 1962* "providing a plan for the integration and guidance of the headlong growth of Adelaide which took place after the Second World War and which . . . tripled its population from 1945 to 1990" (Bunker, 1990). The number of people was 372,000 in 1945, rising to 576,600 in 1960 and 1,044,602 in 1990 (ABS, 2008). This supported further urban expansion in order to promote economic development while meeting requirements of single-family dwellings on their own plot of land (Hutchings, 1993). In 1967, a State Planning Authority was created pursuant to the Planning and Development Act, 1967 (Hutchings, 1988).

The process of urban expansion has been closely associated with State Government promotion of economic development, especially by providing funding and public infrastructure (e.g. a north-south transportation corridor). In the late 1940s the state's public housing authority, the South Australian Housing Trust, built a satellite town, Elizabeth, 24 km north of the central business district (CBD). The new town attracted substantial housing and industrial development, symbolized by the Holden car plant, and population increased quickly in the northern local government areas of Salisbury and Playford (Forster, 1986; Sheridan, 1986). To the south of the city, 30 km south of the CBD, a new centre was developed at Noarlunga, and in the north-eastern suburbs, 17 km from the CBD, Modbury council made use of the concentration of land ownership to build a large retail centre at Tea Tree Plaza. These developments promoted decentralized retail and industrial development accompanied by low-density housing and dependence upon privately owned motor vehicles.

Following McKenzie (1996), Su et al. (2014), we defined the peri-urban fringe as a region of Greater Adelaide designated in *The 30-Year Plan for Greater Adelaide* (DPTISA, 2010) that excludes the central city, its adjacent administrative areas, built-up suburbs to both north and south, and the regional township of Murray Bridge (Fig. 1). This enabled a focus on those areas where the outer edge of residential development has expanded rapidly since 1970, as shown in Fig. 2.

2.2. Quantifying the extent and rate of peri-urban residential development

We used a dataset supplied by the Department of Primary Industries and Regions South Australia (PIRSA) to analyse the process of residential development in Adelaide's peri-urban fringe. With a maximum plot scale of 1:2500, the dataset describes the spatial locations of all buildings within South Australia and their date of construction, across the period from the beginnings of European settlement in 1836 to 2014. We assumed that housing with no construction year recorded existed before 1971, which accounted for 10.7% of all housing stock. Then this study selected those houses built during 1971–2010 in Adelaide's peri-urban fringe.

To measure the extent and rate of residential development, we computed the percent total (PT) and the expansion intensity index (M) as follows (Liu et al., 2000):

$$PT = \frac{U_i}{\sum_{i=1}^{n} U_i} \times 100 \quad (1)$$

$$M = \frac{U_i}{A} \times 100 \quad (2)$$

where U_i is the increase in the area of residential land during phase i of the study period; n is the number of phases; and A represents the total area of the study region.

2.3. Potential driving forces of peri-urban residential development

Table 1 summarizes the selected potential drivers (explanatory variables) of peri-urban residential development:

It is possible to measure the effects of roads and services on peri-urban residential development by examining the accessibility of new housing to them. This includes distance to major roads (*Dis_mroad*) (Batisani and Yarnal, 2009; Cheng, 2011; Dubovyk et al., 2011), distance to the CBD (*Dis_CBD*) (Batisani and Yarnal, 2009; Dubovyk et al., 2011; Hu and Lo, 2007; Poelmans and Van Rompaey, 2010), distance to schools (*Dis_school*) (Liu et al., 2015)

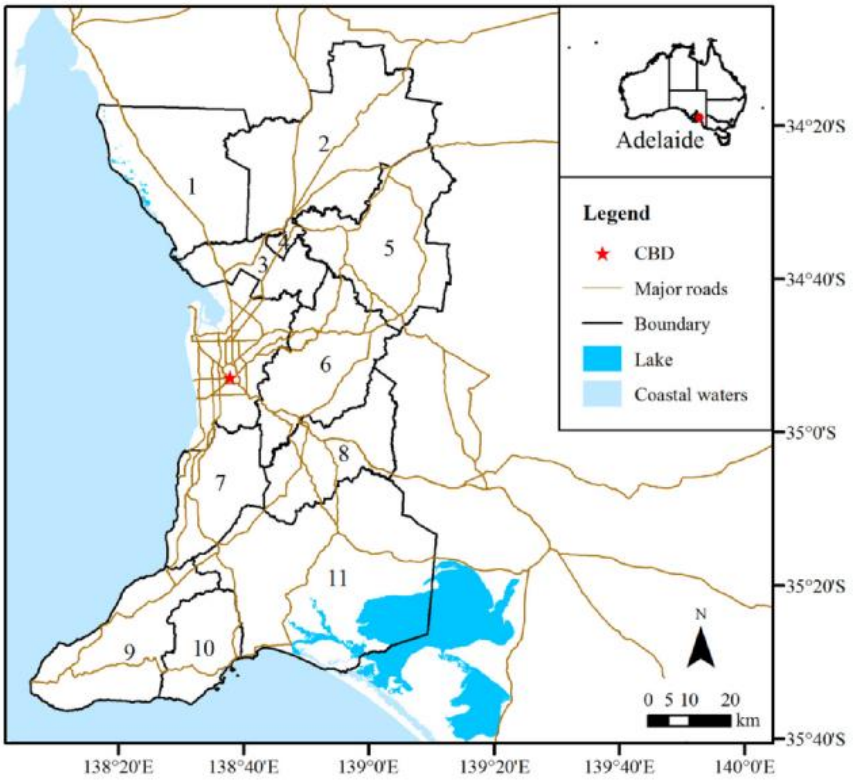

Fig. 1. Location of study area. Local government areas are: 1, Mallala; 2, Light; 3, Playford; 4, Gawler; 5, Barossa; 6, Adelaide Hills; 7, Onkaparinga; 8, Mount Barker; 9, Yankalilla; 10, Victor Harbor; 11, Alexandrina. CBD, central business district.

Table 1
Explanatory variables.

Variable	Description	Minimum	Maximum	Mean	SD
Roads and services					
Dis_mroad (km)	Distance to the nearest major road	0.02	8.59	0.94	0.97
Dis_CBD (km)	Distance to CBD	7.38	89.46	36.30	14.82
Dis_school (km)	Distance to the nearest school	0.02	23.67	3.29	2.60
Dis_hospital (km)	Distance to the nearest hospital	0.08	46.45	10.17	6.30
Natural amenities					
Elevation (m)	Elevation	1.74	641.35	219.59	158.51
Dis_coast (km)	Distance to the nearest coast	0.02	66.40	20.93	12.10
Dis_park (km)	Distance to the nearest park	0.02	43.08	6.98	5.81
Previous residential development					
Den_res (1970)	Density of residential parcels (1970)	0	38	2.96	3.41
Den_res (1980)	Density of residential parcels (1980)	0	37	4.72	4.86
Den_res (1990)	Density of residential parcels (1990)	0	44	8.11	8.39
Den_res (2000)	Density of residential parcels (2000)	0	69	10.90	11.61

Note: SD is the abbreviation for standard deviation.
All explanatory variables are quantitative.

and distance to hospitals (*Dis_hospital*). We extracted highways, freeways, arterial and sub-arterial roads as the major roads from a dataset supplied by the Department of Planning, Transport and Infrastructure South Australia updated on March 13, 2015 (https://data.sa.gov.au/). The definition of the CBD is based on the location of the city's General Post Office. PIRSA datasets supplied information on the location of schools and hospitals.

Desire to locate close to attractive natural amenities can be reflected by elevation, distance to the coast (*Dis_coast*) and distance to parks (*Dis_park*). Higher elevations can exert a positive attraction for new residential development, often of high value (Argent et al., 2007; Filion et al., 1999; McIntyre, 2009). They also receive more precipitation than the coastal plain, which is rather important for this region located in the driest state of Australia, with lack of readily available water significantly constraining agricultural production (Quiggin, 2006). Much of Adelaide's peri-urban fringe is in the Adelaide Hills and Mount Lofty Ranges, which receive significantly more rainfall than in the city and hence offer a 'green' and attractive environment for residents, featuring production of grapes, apples, pears, cherries, strawberries and temperate vegetables as well as areas set aside for conservation. A view of the coast and locations near the coast and/or parks are also prized amenities. PIRSA datasets provided data on elevation at 10-m interval and on

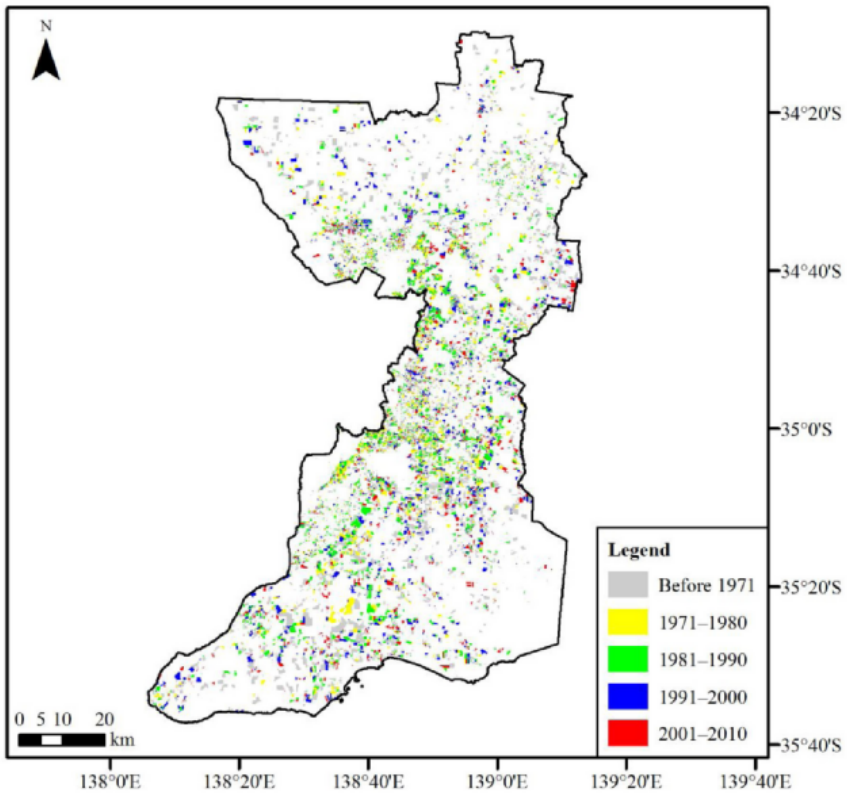

Fig. 2. Residential development in Adelaide's peri-urban fringe (source: Primary Industries and Regions, South Australia).

the locations of parks (including national parks, conservation parks, and recreation parks).

Previous residential development influences new housing construction in adjacent areas because of neighbourhood effects (Dendoncker et al., 2007). New housing is more likely on undeveloped plots located near or adjacent to existing housing, often reflecting zoning designation within planning ordinances. To measure these neighbourhood effects, density of residential parcels (*Den_res*), defined as the number of residential parcels in a buffer zone within a distance of 500 m (Verburg et al., 2004).

All variables mentioned above are in vector format with the same spatial extent, projection, and coordinate system. The "near" tool in ArcGIS 10.2.1 calculated distances from the centre points of residential parcels to major roads, the CBD, schools, hospitals, the coast and parks.

2.4. Statistical analysis

2.4.1. Logistic regression (LR)

Following Menard (2001), the LR models used in this study are:

$$P(Y=1)=\frac{exp(\beta_0+\beta_1x_1+\cdots+\beta_kx_k)}{1+exp(\beta_0+\beta_1x_1+\cdots+\beta_kx_k)} \quad (3)$$

$$Odds=\frac{P(Y=1)}{1-P(Y=1)} \quad (4)$$

$$Logit(Y)=\beta_0+\beta_1x_1+\cdots+\beta_kx_k \quad (5)$$

where P is the probability of the conversion from a non-residential to residential parcel during a period; Y represents the conversion is present or absent, given a value of 1 with conversion and a value of 0 otherwise; x_k is the k-th explanatory variable; β_0 is the intercept; and β_k is the regression coefficient for variable x_k.

We estimated LR models for each period by using version 22 of the SPSS statistical software (SPSS Inc., Chicago, USA). Tolerance (*TOL*) and the variance inflation factor (*VIF*) were calculated (Zhu and Huang, 2006) to diagnose multi-collinearity among explanatory variables; their values should not be less than 0.1 and not greater than 10, respectively (Ozdemir, 2011).

Three indices were calculated to assess the goodness-of-fit of the LR models, including receiver operating characteristic (*ROC*), proportion of correctly predicted (*PCP*) and pseudo R^2. If *ROC* is >0.7, the independent variables provide a good explanation of the dependent variable (Pontius Jr and Schneider, 2001). *PCP* was computed (Luo and Wei, 2009) to test the interpretability of LR results. A value for the pseudo $R^2 > 0.2$ represents a relatively good fit (Clark and Hosking, 1986).

Moran's I index, which is the most commonly used index of spatial autocorrelation (Cliff and Ord, 1981; French et al., 2011; Moran, 1950), measured the spatial residual autocorrelation. An index approaching +1 or −1 indicates strong positive or negative autocorrelation, respectively, while if it approaches zero this shows a random distribution of values (Vasiliev, 1996).

The odds ratio (*OR*) reflects the response of a dependent variable to each unit increase in an explanatory variable. An $OR > 1$ shows that the odds of conversion to new housing increases when the explanatory variable increases; $OR = 1$ means no change; and an $OR < 1$ indicates that the odds of conversion to new housing decreases when the explanatory variable increases (Menard, 2001).

2.4.2. Geographically weighted logistic regression (GWLR)

GWLR methods that extend the traditional regression model allow local parameters to be computed (Fotheringham et al., 2002). The description of GWLR models is as follows:

$$Logit(Y(u_i, v_i)) = \beta_0(u_i, v_i) + \beta_1(u_i, v_i)x_{1i} + \cdots + \beta_k(u_i, v_i)x_{ki} \quad (6)$$

where (u_i, v_i) are the coordinates of location i; $Y(u_i,v_i)$ shows that the conversion from a non-residential parcel i to a residential parcel is present or absent; and $\beta_k(u_i, v_i)$ are values of the continuous function $\beta_k(u, v)$ at location i.

We used the minimized Akaike's information criterion (*AIC*), a measure of the relative quality of statistical models, to determine the optimal bandwidth (Fotheringham et al., 2002). GWLR computations were performed using version 4.0 of the GWR software (Nakaya et al., 2005), which can calculate local regression coefficients and pseudo t values indicating the significance of these coefficients. Estimated coefficients for observed points were interpolated using the local polynomial interpolation method (Rodrigues et al., 2014) provided by ArcGIS for purposes of applying the model across the whole study area, i.e. the entire peri-urban fringe.

2.4.3. Variation partitioning

Variation partitioning quantifies the unique and joint effects of different explanatory variables or groups of explanatory variables (Borcard et al., 1992; Cushman et al., 2012), and therefore provides a good understanding of the relative importance of sets of predictors for a dependent variable (Heikkinen et al., 2005). We used variation partitioning to assess the relative influences of roads and services, natural amenities, and previous residential development in explaining the spatial variation of peri-urban residential development. The study decomposed this variation into seven fractions reflecting the unique and joint contributions of the three groups of variables (Li et al., 2013), computing each fraction using Canoco 5 software (ter Braak and Šmilauer, 2012).

3. Results

Across the four time periods, residential development in Adelaide's peri-urban fringe was fastest during 1981–1990 (Table 2), when an additional 4145 dwellings were constructed; these occupied 295.30 km^2 of the fringe's land area, accounting for 32.07% of the total newly-added area across the forty-year period, with an expansion intensity index of 3.53. This rapid expansion reflected both economic prosperity and a series of policies encouraging new house construction in the 1980s. These included a tax rebate for housing loan interest (1982–1983), First Home Owners Assistance Scheme grants (1983–1991), secondary mortgage market corporations established by the state government (1984–1994), and a support program for low starting 'flexible mortgages' (1984–1994) (Dalton, 2009).

New housing development in the peri-urban fringe grew more slowly, but at similar rates, during the 1970s and the 1990s. A further 3186 and 3205 dwellings respectively were constructed, adding 223.30 km^2 (24.25%) and 234.36 km^2 (25.45%) to the residential land area. Between 2001 and 2010, the growth rate of residential development declined: only 2161 new dwellings, occupying an area of 167.81 km^2, partly related to an increase in housing costs, which restrained the demand for new dwellings. For example, the proportion of dwellings that median younger households can afford declined from almost 75% in the mid-1990s to about 33% by 2006/2007 (DPLG, 2009). There have also been recent moves to promote some new developments within the existing urban envelope. These include planning rules revised to help refocus private-sector interest in the CBD; re-zoning of inner-metropolitan council areas to promote inner-city living; strengthening anti-development laws to the south and north of the city; developing a new 30-year transport plan for the state; and introducing new development initiatives focused on the CBD, including urban renewal legislation (Mannix, 2013). It also seems to reflect some greater acceptance of higher density urban living, as embodied in *The City of Adelaide Strategic Plan 2012–16*, which refers to 15,040 net additional dwellings, 27,300 net additional residents and 50,000 net additional jobs for the city by 2040 (ACC, 2012). These would shift some of the focus away from urban expansion.

3.1. LR models

LR models were estimated for each of the four periods, with values of $TOL > 0.1$ and $VIF < 10$, indicating no multi-collinearity among explanatory variables. As shown in Tables 3 and 4 values of *ROC*, pseudo R^2 and *PCP* were higher than 0.9, 0.5, and 0.85, respectively, which showed that each LR model fitted the data well.

The effects of all explanatory variables on peri-urban residential development varied over time. For the four periods, distance to major roads and distance to the CBD had consistently negative effects on residential development, indicating that the likelihood of new development occurring falls as the distance to both major roads and the CBD grows. An increase in the distance to major roads by 1 km decreased the *OR* of residential development by 27.7, 17.8, 12.5, and 23.9%, respectively for each consecutive time period (these values were calculated as $exp(\beta_k)$-1). This highlights the importance of accessibility to major roads in the residential development process, and also the role played by strategic planning which largely designates new land for development in conjunction with ease of access to transport infrastructure (especially major roads in this case). Furthermore, for an additional 1 km further from the CBD, the *OR* decreased by 5.9, 2.9, 1.1, and 1.3%, respectively, for the four time periods, providing an indication of a gradual reduction in development with movement away from the main built-up area of the city. Distance to schools had a significant influence on peri-urban residential development in the first three periods, with locations in close proximity to existing schools more likely to be developed for new housing. However, this was not the case between 2001 and 2010, which may be associated with the reduction of available land for building near schools and related increases in the price of housing. Proximity to hospitals encouraged peri-urban residential development in the vicinity in the 1970s, but the relationship was not statistically significant during the 1980s. In the two most recent periods, though, the average distance between hospitals and new housing grew, reflecting both the lack of available stocks of land for new development near hospitals and the generally limited hospital provision in the peri-urban fringe.

The attraction of natural amenity, as reflected by elevation, distance to the coast and distance to parks, also affected peri-urban residential development. The positive influence of elevation on residential development except for the period 2001–2010 indicated the attraction of the higher parts of the Adelaide Hills and Mount Lofty Ranges, probably because of their landscape amenity and ease of access to Adelaide city centre via the South-East Freeway. Proximity to the coast also increased the likelihood of new housing development in the first three periods, with coastal views and short travel times to the sea widely perceived as valuable amenities, and hence the growth of coastal suburbs south of Adelaide such as Aldinga, Maslin Beach, Sellicks Beach and Victor Harbor. However, after 2000, the effects of elevation and distance to the coast on peri-urban residential development altered, reflecting changes in the availability of land for development, especially with new sub-divisions permitted away from the higher and coastal areas post-2000. Parks only exerted a significant positive attraction for new development in the most recent decade examined, and had the opposite effect in the 1970s. This may be related to the lack

Table 2
Residential development in Adelaide's peri-urban fringe from 1971 to 2010.

Phases	Number of new dwellings	Expansion area (km^2)	Percent total (%)	Expansion intensity index
1971–1980	3186	223.30	24.25	2.67
1981–1990	4145	295.30	32.07	3.53
1991–2000	3205	234.36	25.45	2.81
2001–2010	2161	167.81	18.22	2.01
Total	12697	920.78	100	11.02

Table 3
Results of the LR models.

Variables	1971–1980		1981–1990		1991–2000		2001–2010	
	β	OR	β	OR	β	OR	β	OR
Roads and services								
Dis_mroad	−0.325***	0.723	−0.196***	0.822	−0.133***	0.875	−0.273***	0.761
Dis_CBD	−0.06***	0.941	−0.03***	0.971	−0.011**	0.989	−0.013**	0.987
Dis_school	−0.108***	0.898	−0.067***	0.935	−0.087***	0.917	0.007	1.007
Dis_hospital	−0.05***	0.952	0.005	1.005	0.019*	1.019	0.058***	1.059
Natural amenities								
Elevation	0.005***	1.005	0.002***	1.002	0.003***	1.003	−0.002**	0.998
Dis_coast	−0.063***	0.939	−0.029***	0.971	−0.022***	0.978	0.023***	1.023
Dis_park	0.036***	1.036	0.005	1.005	0.007	1.007	−0.065***	0.937
Previous residential development								
Den_res	1.504***	4.501	1.515***	4.55	1.793***	6.01	1.531***	4.622
Constant	3.145***	23.22	0.532***	1.702	−0.995***	0.37	−1.358***	0.257
N	6372		8290		6410		4322	
ROC	0.94		0.93		0.94		0.94	
Pseudo R^2	0.59		0.54		0.61		0.61	

Note: OR indicates the odds ratio.
* $P<0.05$.
** $P<0.01$.
*** $P<0.001$.

Table 4
Comparison between the LR and GWLR models.

Period	Model	AIC	PCP	RSS	Moran's *I* of residuals	
					Index	*p* value
1971–1980	LR	3661.78	0.88	547.53	0.058	<0.001
	GWLR	3197.27	0.90	468.99	0.008	<0.001
1981–1990	LR	5282.59	0.86	846.93	0.051	<0.001
	GWLR	4820.58	0.88	717.71	0.003	0.054
1991–2000	LR	3505.20	0.89	537.64	0.021	<0.001
	GWLR	3319.32	0.90	485.28	0.002	0.252
2001–2010	LR	2367.10	0.89	360.65	0.035	<0.001
	GWLR	2174.55	0.93	311.25	−0.005	0.060

Note: RSS is the abbreviation of residual sum of squares.

of public infrastructure in the vicinity of parks in the ealier periods. However, these effects of elevation, distance to the coast and distance to parks were all relatively slight because their *OR*s were almost equal to one. For example, a 1 km increase in distance to the coast decreased the *OR* of residential development by just 6.1%, 2.9% and 2.2% for the first three periods, respectively, and only increased the *OR* by 2.3% for 2001–2010.

In each period, the density of residential parcels positively influenced residential development. This indicates that the greater the density of residential parcels, the greater the likelihood of new residential development in close proximity to existing housing. For example, with an increase in denstity of residential parcels by one, the *OR* of residential development increased by 350.1% for 1971–1980, 355% for 1981–1990, 501% for 1991–2000, and 362.2% for 2001–2010. This suggests the ongoing influence of zoning that consistently locates new development close to pre-existing development.

3.2. GWLR models

Using the same samples, GWLR models showed improvement over LR models (Table 4). First, the reduction in *AIC* suggested that the GWLR models fit the data better than the LR models. Second, the small increase in *PCP* and decrease in the residual sum of squares (*RSS*) indicated that the GWLR models exhibited slightly better performance in exploring the relationships between residential development and the explanatory variables. Third, Moran's *I* indices for LR models were significant at $p<0.001$ for all four time periods, with index values ranging from 0.021 to 0.058, which indicated that weak, positive spatial residual autocorrelation was present and statistically significant. However, Moran's *I* indices for GWLR models were not significant during the last three periods, and declined during 1971–1980, suggesting that the GWLR models have lower levels of spatial residual autocorrelation than the LR models.

The surfaces of the parameters estimated from the GWLR technique, which can be used to measure and map local spatial

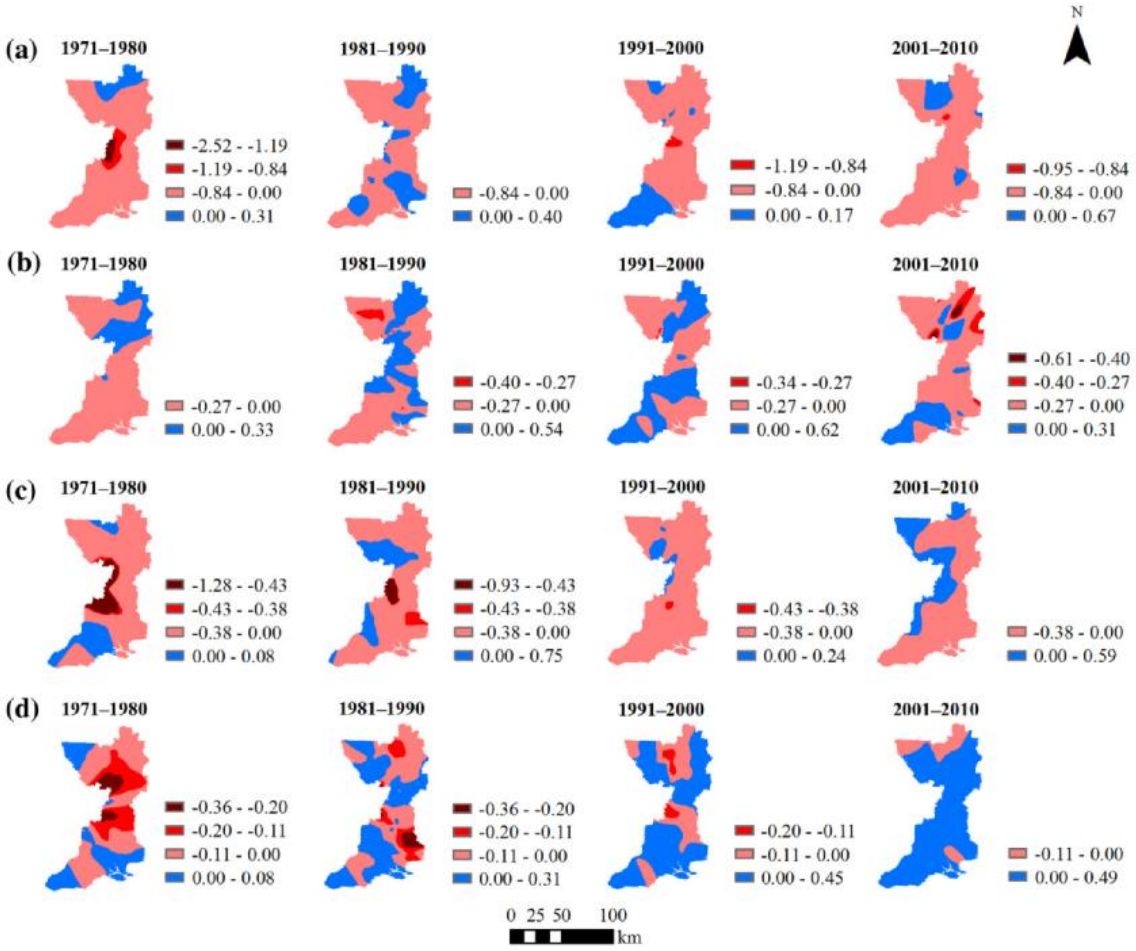

Fig. 3. GWLR parameter surfaces for (a) the distance to major roads, (b) distance to CBD, (c) distance to schools and (d) distance to hospitals.

relationships (Fotheringham et al., 2002), are helpful in exploring parameter heterogeneity across space. Fig. 3a depicts the spatio-temporal relationships between distance to major roads and peri-urban residential development. In accordance with the LR models, the distance to major roads in large parts of Adelaide's peri-urban fringe showed the expected relationship, i.e., residential development is more likely to occur near major roads. Areas in which this covariate had stronger negative impacts on residential development were located in central parts of the fringe during the 1970s and reduced in size, even disappearing, during the last three periods, implying that the effects of distance to major roads on peri-urban residential development possibly weakened. Compared with distance to major roads, the distance to the CBD showed smaller areas of negative effects on residential development, with stronger negative effects in the north-east after 2000 than in other parts of the study area (Fig. 3b). The negative influences of distance to schools were noticeable in the central fringe during 1971–1980 (Fig. 3c). Areas with these stronger negative impacts decreased in size during the last three time-periods, which may be related to the rise of housing costs near schools. Distance to hospitals had negative impacts on peri-urban residential development in most of the study region in the 1970s (Fig. 3d). However, areas with positive effects of this predictor consistently expanded in size to cover large parts of the study area during last two time-periods. This may explain the transition of estimated coefficients for distance to hospitals, from negative to positive impacts, in the LR models.

The effects of elevation on the distribution of residential development were positive in most of the study area for the first three time periods, and regions with higher positive effects decreased in size during the 1980s and 1990s compared with the 1970s (Fig. 4a), linked closely to the timing of major new housing developments. However, the sign of the estimated coefficients for elevation became negative in the majority of the peri-urban fringe between 2001 and 2010, possibly related to controls on land available for development and the rise of housing prices in locales with higher elevation. The area over which proximity to the coast encouraged new residential development reduced in size over time (Fig. 4b), largely associated with the stronger planning controls. Peri-urban residential development tended not to locate close to parks during the 1970s, but by the most recent time-period considered it had become more common for sub-divisions for development to be designated close to some parks (Fig. 4c), often for high-cost dwellings.

In accordance with the LR models, the effects of residential parcel density on new housing development were positive throughout the study area for all periods (Fig. 4d). However, these positive effects also varied spatially, being more pronounced in the central fringe than other parts of the study area during the 1970s and 1990s,

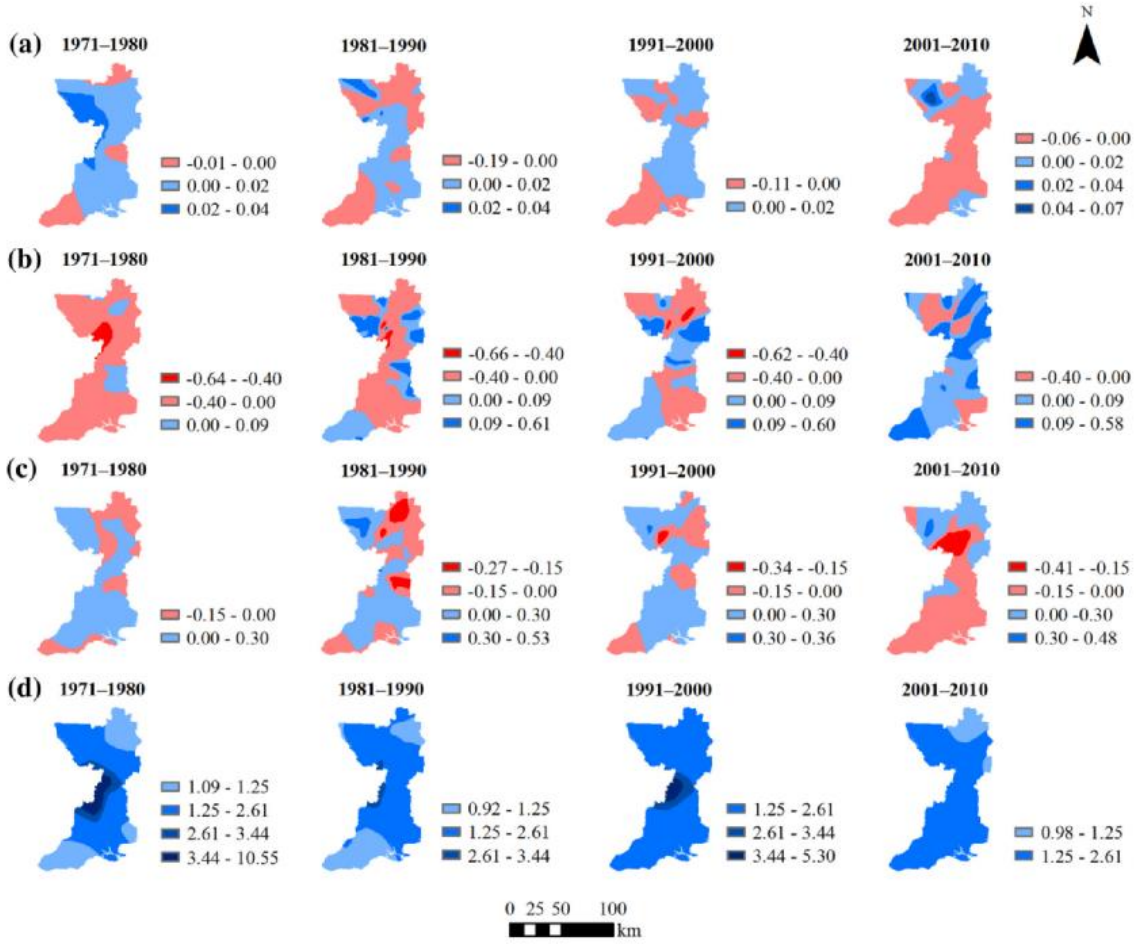

Fig. 4. GWLR parameter surfaces for (a) elevation, (b) distance to coast, (c) distance to parks and (d) the density of residential parcels.

probably reflecting the pattern and timing of significant releases of land for development.

3.3. Variation partitioning

The results of variation partitioning highlighted the relative importance of the 'driving forces' listed in Table 1. The unique effects of roads and services, natural amenities, and previous residential development on new housing development varied over time (Fig. 5). Roads and services (a) had the greatest impacts on residential development during the 1970s, when previous residential development (c) had the second-strongest effects. The unique contribution of roads and services consistently decreased over time, while the pure contribution of previous residential development rose steadily. After the 1970s, roads and services ranked second behind previous residential development. Proximity to natural amenities (b) was of least importance among the three groups of driving forces for all of the periods. In terms of joint contributions, the combination of roads and services and previous residential development (f) was most important during all four periods (between 13 to 16% of all explained variation). Essentially this highlights the importance of roads and services and previous residential development, both singularly and in combination, as key factors in affecting the location of new housing development in the

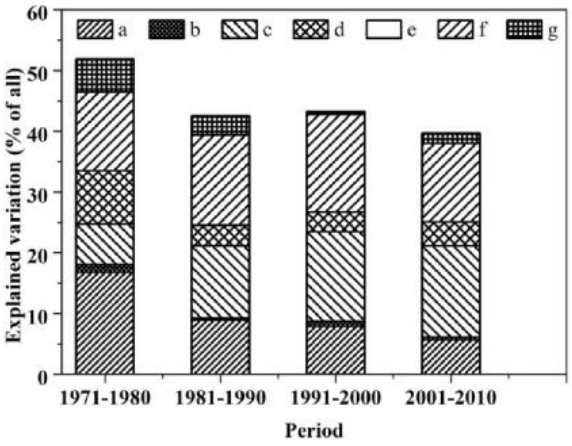

Fig. 5. Results of variation partitioning to determine the unique contributions of: (a) roads and services, (b) natural amenities, (c) previous residential development, and the joint contributions of (d) roads and services and natural amenities, (e) natural amenities and previous residential development, (f) roads and services and previous residential development, and (g) roads and services, natural amenities, and previous residential development.

peri-urban fringe. The joint contributions of natural amenities and previous residential development (e) were close to zero, indicating that most of the relationships between them were suppressive (Chevan and Sutherland, 1991). However, in each of the four periods, the single and combined group of variables only explained half of the overall variation in housing development. Hence, factors not measured and analysed herewith are equally important in accounting for the spatial pattern of development. The limitations of the analysis are discussed further below.

4. Discussion

4.1. Driving forces of peri-urban residential development

4.1.1. Roads and services

This study confirmed the strong effects of road infrastructure and services on residential development patterns in Adelaide's peri-urban fringe. The unique contribution of road expansion and associated services to peri-urban residential development ranked first in the 1970s among the three groups of explanatory variables (44% of all variation explained singly and in combination with other groups of variables). Its importance fell subsequently, though it still ranked second in terms of importance in the last three periods, explaining between 24% and 30% of total variation singly and in combination. The reduction in relative importance of roads and services was possibly associated with that distance to schools and to hospitals did not maintain a consistent influence on peri-urban residential development over time. Specifically, close proximity to existing hospitals did not accompany new peri-urban residential development after the 1970s, though such development remained closely tied to the location of existing schools until 2000.

With regard to the role of roads and services in driving the pattern of residential development, the results clearly highlight the importance of strategic planning, with different regional plans throughout the forty years shaping both the building of new roads and release of new land for housing. The extent of road and house building has varied over time, in part reflecting growing concerns about the negative impacts of urban expansion on agriculture, biodiversity and water supply (McFarland, 2015), but the impact of strategic planning has been crucial. For example, the *Report on the Metropolitan Area of Adelaide* set the agenda for development between 1962 and 1991. The *Report* proposed that the 'living zone' for residents should be located where services such as roads could be supplied economically, with a strategy to focus on certain areas of the peri-urban fringe (including southwards along the coast) where new roads would accompany housing development (Town Planning Committee, 1962). With the implementation of the Planning and Development Act of 1967, developers had to supply services when sub-divisions for new development were established (DPLG, 2009).

In the past two decades, strategic planning for Greater Adelaide has increasingly focused on a policy of urban consolidation to promote a more compact form of urban development. Specifically, it restricted rapid urban development, focused expansion to two areas of the metropolitan fringe (in the south-east and north), and created a Metropolitan Open Space System (MOSS) to maintain the open and spacious character of Adelaide, principally incorporating the scarp face of the Adelaide Hills and Mount Lofty Ranges (DEPSA, 1992). As Adelaide continues to expand and the distance from the fringe areas to the CBD and major employment centres becomes greater, ease of access to major roads and suburban train lines may become an increasingly important issue. For example, *South Australia's Strategic Plan* in 2004 and its revision in 2007 (South Australia's Strategic Plan Update Team, 2007) stressed that the development of settlements should be concentrated along transportation corridors. The *Strategic Infrastructure Plan for South Australia 2005/6–2014/15* (Office for Infrastructure Development, 2005) also emphasized that new residential developments should have access to adequate infrastructure, such as transportation and service centres, further highlighting the importance of key centres in the fringe, such as Mount Barker and Gawler.

4.1.2. Attraction of natural amenities

There was an association between peri-urban residential development and both higher elevation and close proximity to the coast in the first three periods and with accessibility to parks in the final period. This is consistent with amenity-based theory describing that wealthier households tend to choose those locations with strong amenity advantage (Brueckner et al., 1999). Across much of Adelaide's peri-urban fringe and indeed in those elsewhere in Australia, poorer families have often been priced out of the housing market in those locales close to area of highest amenity (e.g. areas of high scenic quality) (Beer et al., 2007).

However, their impacts on peri-urban residential development were weak according to the LR results. The importance of natural amenity in explaining variation amongst the three groups of variables was slight (<16% of all variation explained singly and in combination with other groups of variables) in any of the four decades. This reflects strong zoning and planning controls. For example, the limited availability of land for development in close proximity to much of the fringe's parks (e.g., national parks, conservation parks) has severely restricted growth of new housing in these locales.

4.1.3. Previous residential development

The contribution of previous residential development to new housing development in the peri-urban fringe grew strongly over time, indicating that new housing units were increasingly infilling open space near existing homes. The results essentially mirror the impacts of zoning for new residential development in Adelaide's peri-urban fringe, allied to the ability of many landowners to sub-divide land for development purposes (Bunker et al., 2005; McKenzie, 1997). Planning rules enshrined in South Australian law (e.g. the Development Act 1993) permitted sub-division of existing plots of land, including some farmland, for housing development involving detached dwellings. There has also been sub-division of broad-acre farmland into special rural plots rezoned or formally adopted under town planning schemes.

These results correspond with the findings for an urbanizing county in Ohio, where new residential development has tended to be located in proximity to the existing urban area (Carrión-Flores and Irwin, 2004), and are corroborated by the work of Wilson and Song (2010) for Charlotte, North Carolina where large residential subdivisions were positively related to subsequent subdivisions. In contrast, our results differ from those reported in some other parts of the US. For example, Irwin and Bockstael (2002) found for exurban Maryland that undeveloped land adjoining developed land was less likely to be used for future residential development.

4.2. Methodological implications and limitations

To better understand the complex relationships between residential development and factors affecting its location, we developed global (LR) and local (GWLR) models for identifying and examining the effects of road expansion and services, attraction of natural amenities, and previous residential development on new residential development in Adelaide's peri-urban fringe. The results demonstrated that GWLR models provide deeper insights into spatial variations (Luo and Wei, 2009) in the relationships between residential development and its drivers. They had better goodness-of-fit and lower levels of spatial residual autocorrelation and thus

outperformed the LR models. These results are consistent with previous studies of the relationships between response variables and their predictors, such as in the analysis of urban growth in Mumbai, India (Shafizadeh-Moghadam and Helbich, 2015) and Nanjing, China (Luo and Wei, 2009), in the afforestation of Northeast China (Zhen et al., 2013), and for wildfires in Spain (Rodrigues et al., 2014). Further, variation partitioning was used to measure the relative importance of the three categories of forces to peri-urban residential development, which was helpful to develop corresponding policy responses.

As this was an exploratory study we focused on a relatively small number of variables, arranged under three distinct categories. Although exploratory, the results add to existing knowledge on development in the peri-urban fringe by using LR and GWLR models to recognise the spatial determinants of peri-urban residential development and variation partitioning to test their relative importance. Essentially, the measured variables employed in this study explained half of the variation recorded in the spatial pattern of new residential development. However, they excluded consideration of some potentially influential variables underlying peri-urban residential development. For example, the effects of subdivision are not captured in the data utilised herewith, although increasing fragmentation of land is an integral part of the urban development process prior to house construction. Moreover, household characters such as income, household size and composition also potentially affect the pattern of peri-urban residential development.

Adding further variables may have increased the explanatory power of the model, but with unmeasurable factors still ensuring some unexplained variation. It is difficult to measure certain variables on the same spatial and temporal scales as those in this study, but dummy variables for income and household size were tested using median weekly personal incomes and household size for each local government area. Two dummy variables for median weekly personal incomes (*DI*) and household size (*DHS*) were added to the existing eight explanatory variables.

Now with ten explanatory variables (the eight original plus the two dummies), LR models were re-estimated. The results showed that *DI* had significantly positive effects on peri-urban residential development in the 1980s, but was not statistically significant in other three time-periods. Household size exerted significantly negative impacts during 1971–1980 and 2001–2010, but was insignificant in the other two periods. Conducting variation partitioning with *DI* and *DHS* included in the group for road expansion and services, raised the percentage of total explained variation by less than one for all four periods. To extend this investigation of the impact of income, household size and other characteristics relating to the decisions of households and individuals, the next phase of this research will survey individual households with a range of questions asked about their decision to locate in the peri-urban fringe (see Chadbourne, 2015).

4.3. Policy implications

The results highlight the importance of the evolving nature of strategic planning and zoning regulations since the early 1960s in forming the patterns of peri-urban residential development. The tendency to equate economic growth with increased urban expansion, essentially catering to the desire of the middle classes to live in a detached home on their own block of land, has partially given way in planning terms to attempts to create higher density urban living closer to the city centre and major suburban service centres. Yet the ongoing presence of new housing developments in the peri-urban fringe shows that peri-urbanisation has not entirely abated. Indeed, they are catered for in the latest strategic plan, in which residential development has been divided into three categories, namely corridor, non-corridor or fringe, and non-metropolitan townships, thereby permitting significant developments in parts of the fringe, especially near existing service centres, such as Mount Barker (Bunker, 2015; DPLG, 2009).

For Adelaide, land-use planning highlights the role of transport in directing residential development. The tendency for new housing to be significantly affected by transport development (and especially roads) is likely to be strengthened due to the implementation of *The 30-Year Plan for Greater Adelaide*, which was released in 2010 (DPTISA, 2010). The *Plan* proposes that, "wherever possible, new and existing housing should be located close to transport". Hence, the proportions of new dwellings constructed in and around transit corridors were 43.5% in 2010, 48.1% in 2011, and 41% in the first half of 2012 (Bunker, 2015). These were lower than the target (60%) proposed by *The 30-Year Plan*, although the proportion should rise "as local development plans are amended following structure planning" (DPTISA, 2013). Thus, more attention needs to be given to short- and medium-term prospects of new housing construction in metropolitan Adelaide (Bunker, 2015), which could be helpful to ease pressures associated with peri-urban residential development.

The 30-Year Plan emphasizes consolidation of new development in the city itself, but recognizes the need for further expansion of key service centres in the peri-urban fringe to help accommodate the predicted population growth of 560,000 people by 2036 (DPTISA, 2010). Proposed zoning to accommodate new housing in the fringe, partly used to meet people's desire to live close to natural amenities, highlights the ongoing tensions between maintenance of prime agricultural land and nature conservation areas on the one hand and demand for development on green-field sites on the other. For example, prime farmland will continue to be lost to development in the fringe, where 56% of land lost to development since 1970 was categorized as Class 1 and 2 for crop potential (Robinson and Liu, 2015). Therefore, there is a need for policymakers working in this field to identify values for peri-urban landscape (e.g., agricultural land) (Ives and Kendal, 2013) and to consider the impacts of development on these values when making land-use decisions.

An added dimension in the more densely vegetated parts of the peri-urban fringe is risk of bushfires. For example, the Sampson Flat fire in January 2015 burnt 12,500 ha in the fringe, destroying 38 houses (ABC, 2015). So further peri-urban development may not only be antithetical to maintenance of biodiversity, but may pose physical risk to new inhabitants (Bardsley et al., 2015). In conjunction with other problems associated with new housing development in the fringe, this will need to be tackled through greater co-operation between the various local authorities and the different branches of government. There may also be a need to rethink how strategic plans are formulated and what new methods can be used to control and direct development, such as scenario planning specifically for the fringe (Buxton et al., 2011) and a peri-urban landscapes values-led planning approach (Ives and Kendal, 2013).

5. Conclusions

This paper has focused on new housing development occurring in the peri-urban fringe of Adelaide, using an exploratory analytic approach to investigate some of the key readily measurable factors underlying the spatial pattern of development. It analysed the changing impacts of eight explanatory variables across a forty-year period and their interaction with an evolving policy environment. The links between the policies and the variables have occurred within the context of shifts in strategic planning that at different times have supported both peri-urbanisation and compact tendencies in urban development. The long-term dynamic of urban

expansion as an integral component of urban and economic growth has been tempered somewhat by measures to 'densify' the city, but not entirely at the expense of new development in the peri-urban fringe associated with zoning for growth around key centres and in conjunction with new transport infrastructure.

The growth rate of new housing in the peri-urban fringe fluctuated over the four decades studied, with the number and occupied land area of new housing increasing most rapidly during the 1980s, with a subsequent decline, pronounced after 2000. For the selected explanatory variables, road expansion and associated services had the greatest impacts on residential development in the 1970s, with new housing built close to transportation links under strategic planning guidelines. Its influence declined subsequently and it was ranked second in terms of the importance to peri-urban residential development in the remaining time-periods. The effects of the attraction of natural amenities were of the least importance among the three types of driving forces, whereas that of previous residential development consistently increased in importance over time.

In terms of the statistical methods employed, GWLR models possessed higher goodness-of-fit and lower spatial residual autocorrelation than the LR models, and they were able to show how the estimated coefficients varied spatially. Potentially, explorations of this spatial dimension can highlight processes and mechanisms responsible for the changes in peri-urban fringes to assist in the design of planning and policy responses. Further examination of a greater range of independent variables could sharpen and improve the explanatory power of this approach.

In the case of Adelaide, land-use planning and policy has played a major role in directing peri-urban residential development through locating new housing in conjunction with both major highway developments, expansion of the local road network and subdivision of previously undeveloped areas. Some pointers emerging from the analysis include the following. First, short- and medium-term prospects for residential growth within the existing urban area merit more attention to help reduce the various pressures associated with peri-urban residential development. Second, policymakers should attach greater value to maintaining and improving the quality of peri-urban landscapes when formulating strategic land-use plans. Third, it is necessary to strengthen cooperation between local authorities and the various departments of state government. In addition, there may also be a need to apply new methods to future strategic plans, such as scenario planning specifically for the fringe (Buxton et al., 2011) and/or employing a values-led planning approach (Ives and Kendal, 2013).

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Review

Preserving Farmland on the Urban Fringe: A Literature Review on Land Policies in Developed Countries

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Abstract: This paper reviews the recent literature dealing with farmland protection (FP) policies in developed countries from a planning perspective, with a specific focus on the Mediterranean region. It provides coverage of French language papers that may have been omitted in previous reviews. While the Mediterranean is often pointed out as a region with acute challenges related to food security and a lack of effective planning policies, the literature underlines that issues related to FP policies are similar across the world. Hence, this review may bring valuable insights for more sustainable management of farmland on the urban fringe. It maps several interesting areas of research concerning the often implicit and disparate rationales of FP policies as well as the barriers and potential avenues for improvement for FP. It highlights that FP cannot rely merely on transferring policy tools that have proven successful elsewhere. It also reveals that land policies do not always take into account the specific needs of farming systems, as they often focus on land rather than on agriculture. Further research is thus needed to reveal the interaction over time between the use of certain FP tools and the unique local features of urban fringe agriculture. This review may be of interest to students and scholars, but also to practitioners, policy makers and local groups looking for innovative, more flexible or locally suited farmland protection programs.

Keywords: farmland protection; peri-urban agriculture; land-use planning

1. Introduction

Farmland preservation is a longstanding challenge on the urban fringe [1,2]. In the last two decades, farmland loss has increasingly become a worldwide matter of concern, both for environmental and food security reasons [3]. In all developed countries, as well as in some developing and emerging countries, there is debate about how farmland conversion to urban uses should be governed [4].

Extensive scientific literature is devoted to the issue of farmland preservation on the urban fringe, which involves planners, agricultural economists, geographers, and other social scientists. Scholars have provided a good overview of the range of land policy instruments tested around the world. The tool box features land-use regulation, acquisition (or transfer) of land or development rights, and incentive-based approaches [5]. Law scholars have shown that their preferential use varies according to the country [6]. Depending on local property rights and land-use regulations, the same tool (e.g., zoning) may be used for different planning practices in the United States and Europe [7].

In this paper, it is not our objective to describe and assess farmland protection (FP) techniques, as some scholars have already provided comparative evaluations [8]. Our focus on planning literature

aims to draw lessons from policy alternatives and local initiatives with regard to the way they take farming into account by answering the following questions: what are the rationales for FP? What are the main barriers and challenges hampering FP programs' efficacy and the inclusion of farming issues in land policies? Can we point towards future policy directions or research avenues? How could FP policies better maintain farming while meeting public preferences on the urban fringe?

Our methodological approach consists of a review of scientific papers published in English and French on FP in the face of urbanization, with a particular focus on the Mediterranean region. While such a topic is multidisciplinary by nature, we concentrate on qualitative studies conducted in planning, geography, sociology and political science. Our review cites a few key economics references, but does not cover the extensive existing literature on this topic in agricultural and land-use economics. While farmland preservation has recently become a major issue in emerging countries, especially in China [9,10], we consider that the issue of FP in such countries would deserve separate reviews in order to take into account their specific property regimes and land-use regulations. Hence, we narrowed our literature review to developed countries and to the Mediterranean region, thanks to our access to the French-language literature and with a view to this paper's inclusion in the special issue of the *Land* journal on "Land and Farming System Dynamics on the Mediterranean Basin: From Global to Local Case Studies".

Farmland preservation is particularly urgent in the Mediterranean; we identified research on this topic in all European countries in the region, as well as in the Maghreb, Lebanon and in Israel. In the last two decades, the Mediterranean has undergone an intense urbanization process, mainly at the expense of prime agricultural land, since cities are historically located in the most fertile coastal plains [11] and tourist activities have increased urban sprawl on the coasts [12,13]. Land tenure varies across regions. Around cities, it may be very fragmented amongst private smallholders or owned by a few large landowners that are public, religious (*habous* or *waqf* lands) or private [14–16]. Mediterranean farming systems are under particular pressure from climate change and soil degradation, increasing the challenges related to food and water security [17]. Farming is also jeopardized by the risk of land abandonment, which stems from the rural exodus as well as from the pressure to convert farmland for urban uses in peri-urban areas [18,19]. In this context, Mediterranean peri-urban agro-ecosystems show contrasting dynamics, ranging from decline to adaptation to urban demands [20,21]. Diversification activities, both agricultural (social farming, educational farms) and non-agricultural (tourism, energy), as well as the supply of services to the cities, are increasing on peri-urban farms, at least in Northern Mediterranean countries. They facilitate the integration of agricultural producers into short supply chains. However, while they appear in some cases as a rewarding strategy and a successful response to urban pressure, in other cases they can seem a "last attempt" to adapt before abandonment [19]. Such diversification activities often raise a need for specific building rights to implement the multiple 'farm to fork' steps requiring more than the usual farm buildings for storage of products or machines and shelter for animals. For example, farmers seeking better integration into local supply chains may claim building rights related to on-farm processing and conditioning of products, distribution hubs and on-farm shops or accommodation for agri-tourism. In peri-urban areas, planning authorities thus have to arbitrate between different interests, finding innovative ways to preserve farmland from further urban sprawl, while considering claims for the right to build structures needed for multifunctional farming projects [12,15]. This brings into question the efficacy of local policies dedicated to FP on the urban fringe [22].

The results of this literature review on developed countries are presented in three sections: we first give insights into the rationales for FP, then into the barriers to FP and finally into the avenues of improvement for public policy and future research. Before proceeding, we detail our material and methods.

2. Materials and Methods

This literature review covers 104 papers from 22 journals. This corpus was built on a combination of two methods.

First, we searched the SCOPUS and WOS databases for all papers dealing with farmland preservation/protection in the face of urbanization. The words "protection" and "preservation" are both relevant. "Preservation" is more frequent where tools are incentive-based, while "protection" is used where the approach is regulatory. However, some papers use these terms interchangeably, sometimes even employing the term "conservation". We thus used the keywords "protection", "conservation", and "preservation" in association with "farmland" and "urban"[1]. Taking into account that some papers were identified both in WOS and SCOPUS, this query resulted in a corpus of 200 unique references from 89 scientific journals, 60 of which contained only one reference. China (with 88 papers) and the United States (with 64 papers) stood out as the prime areas studied. This corpus omitted some papers that we considered important and counted only 12 papers on the Mediterranean region.

Second, we conducted a manual search of 30 journals: the 7 English-speaking journals with more than 5 references in this WOS-SCOPUS corpus[2] and 23 other journals (15 in French[3] and 8 in English[4]) from the field of geography and planning. We scanned all issues of these journals since 1995, reading the titles, keywords and some abstracts, and added 141 relevant papers to our corpus (Figure 1).

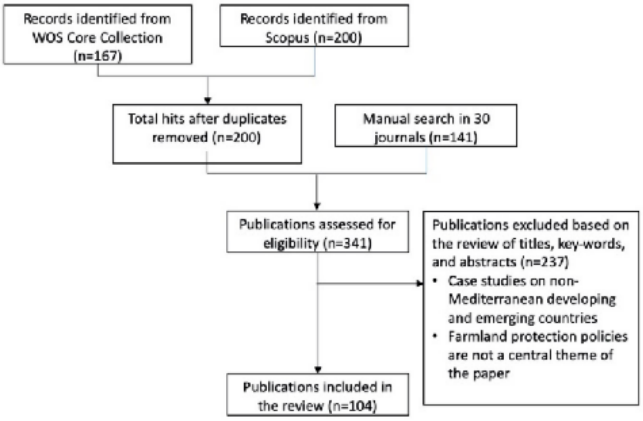

Figure 1. Flow diagram of the selection process.

[1] In the SCOPUS database, we found 200 references through the query: (TITLE-ABS-KEY ("farmland preservation" OR "preservation of farmland" OR "farmland conservation" OR "conservation of farmland" OR "farmland protection" OR "protection of farmland") AND TITLE-ABS-KEY (*urban*)) AND SUBJAREA (mult OR agri OR bioc OR immu OR neur OR phar OR mult OR arts OR busi OR deci OR econ OR psyc OR soci). In the WOS database, we found in May 2020 167 references through the query: (TS = ("Farmland preservation" or "preservation of farmland") AND TS = (*urban*)) OR (TS = ("farmland protection" or "protection of farmland") AND TS = (*urban*)) OR (TS = ("farmland conservation" or "conservation of farmland") AND TS = (*urban*)). Indexes = SCI-EXPANDED, SSCI Timespan = All years.

[2] The journals with 5 papers or more in the WOS-SCOPUS query were *Land Use Policy* (32 papers), *Transactions of the Chinese Society of Agricultural Engineering* (19 papers in Chinese, not included in our analysis), *Sustainability* (19), *Journal of Soil and Water Conservation* (12), *Journal of the American Planning Association* (7), *Landscape and Urban Planning* (7), *Habitat International* (7), and *Journal of Rural Studies* (5).

[3] The selection of French journals was based on their ranking by the French High Council for the Evaluation of Research and Higher Education (HCERES) and their interest in the Mediterranean region: *Economie rurale*, *Revue d'économie régionale et urbaine*, *Norois*, *Géocarrefour*, *Développement durable et territoire*, *Méditerranée*, *Espaces et sociétés*, *VertigO–la revue électronique en sciences de l'environnement*, *Sud-Ouest européen*, *Annales de géographie*, *Géographie, économie et société*, *Etudes Rurales*, *L'Espace géographique*, *Options Méditerranéennes*, and *Cahiers Agriculture*.

[4] *Journal of Planning Literature*, *Agriculture and Human Values*, *Urban Studies*, *Environment and Planning C: Government and Policy*, *Environment and Planning D: Society and Space*, *Geoforum*, *Journal of Urban Planning and Development* and *Geographical Research*.

From this corpus of 341 papers, we excluded those on non-Mediterranean developing and emerging countries and those presenting only spatial analyses of farmland conversion without considering farmland protection mechanisms. We looked specifically for papers on the Mediterranean region and on public policies. We sorted the remaining papers into a mind-map diagram according to their focus on the following topics: the rationales for FP policies, the diversity of tools and stakeholders in farmland preservation policies, the importance of spatial, social and political contexts for understanding farmland preservation mechanisms and the impacts of FP. Figure 2 provides an overview of the categories and sub-categories identified through this review of titles, key-words and abstracts, in a mind-map diagram.

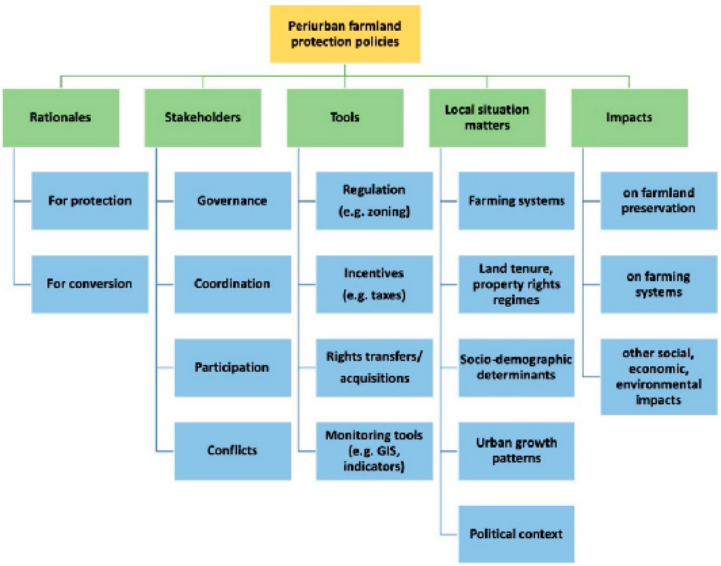

Figure 2. Mind-map diagram of the topics identified through the review of titles, key-words and abstracts.

Based on these two corpora built on a query in WOS-SCOPUS and a manual search, as well as on this mind-map diagram, we selected 104 papers to read. The main journal is *Land Use Policy*, with 45 papers, followed by *Landscape and Urban Planning*, with 18 papers. The remaining 41 papers are distributed among 20 journals, 12 in French and 8 in English. To proceed with reading and comparative analysis of the papers, we developed a standardized form to be filled with the main information we would collect from the papers, namely: the scale of analysis, the location of the case study, the FP instruments, the main actors, the factors for the success or failure of FP, the field or discipline, the research question(s) and method(s), and the avenues for future research. The results of this literature review shed light on the rationales behind FP, on the barriers to effective FP and on avenues of improvement for research and public policies.

3. Differing Rationales for Farmland Protection: Maintaining Farming is Not Always the Priority

Farmland preservation is often presented as an unquestionable necessity. However, since the 1970s, research has raised the questions as to why and for whom farmland should be preserved, uncovering diverse rationales [23]. Today, there is still no consensus about why farmland preservation is important.

3.1. Implicit, Changing, or Disparate Rationales for Farmland Protection

FP objectives are often not explicit [24]. The ambiguity lies primarily in policy framing. Agriculture itself may be overlooked or neglected because there are other overarching priorities: on one hand, social housing and employment issues may legitimize urban development, for instance in the Maghreb [20]

and Israel [25] and, on the other hand, environment or landscape preservation, rather than agriculture, may legitimize urban containment and open space protection in public preferences [26–28]. In triangular planning models that do oppose agriculture, nature and urban development [29], "nature and agriculture often stand in opposition in the quest for land" [30]. FP may also be conceived as an interim stage before projected urban development, as mentioned in Japan [31] or Israel [32].

Where FP is an explicit long-term priority, the rationales that legitimize such policies vary. Objectives for a given farmland or open-space preservation program may change over time and space [33]. For example, Amati and Yokohari [34] observe that contiguous municipalities assign different functions to the London Green Belt. Feitelson [35] illustrates the shifting rationales of the FP program in Israel since the 1960s: the program has moved from productionist arguments (farmland as a resource for food or as an economic sector) to an urban-centered perspective (farmland preservation as a growth management tool to regulate urban sprawl) and environmentalist arguments (concerns over loss of positive externalities). By 1977, Gardner [23], albeit skeptical about removing land allocation from market mechanisms, had already outlined four potential benefits that could reinforce the public legitimacy of FP policies: food security, economic benefits derived from a viable agricultural industry, open space and environmental amenities, and sounder urban development.

While there is no evidence that such varying or combined rationales hinder FP programs' efficacy, scholars have underlined the heterogeneous nature of the stakeholders who support FP. In Canada, Spaling and Wood [36] identify disparate ethical views about FP and "anomalous alliances among interest groups with seemingly different land policy objectives". Similarly, Bunce [37] examines the public discourse of the North American FP movement and the ideologies underpinning it over a 30 year period. He shows how the policy agenda has largely been controlled by non-farming interests, influenced by environmentalist and agrarian ideologies with alternating visions of farming for food production, ecological conservation, or rural authenticity. In the case of Israel too, "the rationales are used to cobble a coalition of planners, environmentalists, farmers, urbanites and exurbanites, against a powerful development coalition" [35].

So whom, in the end, is farmland being preserved for? In some programs, farmers formed the original political support behind FP and were included in the process of elaboration [2]. In the state of Oregon, some farmers still support the programs, while others count among the landowners bristling for change and claiming compensation for the foregone increases in land prices in the 2000s [38]. In other programs, residents' quality of life is the main driver and public focus is on farmland, rather than on farming. In such cases, scholars warn that "without expanding its focus beyond farmland to encompass farming and farmers, the movement risks losing both integrity and effectiveness" [39]. Farmers may be cast in the role of guarantors of food supply and stewards of landscape, rural heritage and community values [40].

Such combined rationales appear in Mediterranean countries and elsewhere. From a critical perspective, research on FP rationales reveals who defines and controls the FP agenda and whose interests it really serves. It clarifies why FP remains a contentious policy issue.

3.2. Farmland Protection as a Contentious Policy Issue

On the urban fringe, many conflicts are related to FP. Since the 1970s, scholars have highlighted equity implications of FP instruments [23,41–43]. Conflicts first place in opposition local authorities implementing the FP policies and landowners wishing to lock in the land value increase [44]. Conflicts are also linked to place-based collective efforts to prevent the negative impacts of urbanization on agrarian landscapes. In such cases, FP often appears to be "window dressing" for other goals [39] that are not directly linked to agricultural interests. In the Greater Paris Region (France), urbanization projects are contested mainly by opponents of farmland conversion. Some residents seem more concerned about illegal occupations of fallow land (especially by gypsy communities) than about the abandonment of farming itself [45]. In Swiss villages, residents protest against dense urban developments by denouncing the visual nuisance and the loss of landscape [46]. Similarly, Pacione [47]

points out that fear of increasing road traffic is the overwhelming argument put forward by residents in the public consultation proceedings for the preservation of the Glasgow greenbelt. Hence, protection of local amenities is a key argument when residents and associations get involved in FP movements.

In the Mediterranean, land-use conflicts over farmland are increased by the scarcity of the resource, as farming is often in intense competition with both residential and touristic uses. The Huerta de Valencia is a good example of such a situation, as its peri-urban agricultural systems are also valuable as an important cultural, natural and landscape heritage [48]. On the French island of Corsica as well, many conflicts arose over the implementation of land-use restrictions on the coast [49].

3.3. Taking Differing Rationales into Account in Policy Design

Research on rationales for FP has practical policy implications. Revealing that heterogeneous coalitions of stakeholders and disparate farmland ethics are involved in land issues on the urban fringe may suggest policy options and decision-making tools that reduce land-use conflicts [36]. Place attachment is often identified as a strong motivation for FP [28,50]. In addition, peri-urban agricultural landscapes are valued by the urban public for a range of functions not typically included in land-use policies [51,52]. This knowledge can assist policy makers in prioritizing which areas to preserve. Using focus groups and surveys of residents to identify public preference, Kline and Wichelns [53] show that FP programs should consider not only farmland or farming (or prime farmland) but also the farming style (e.g., environmentally friendly farming). In comparing the mission statements of 130 land trusts engaged in FP, Brinkley [54] similarly finds "uniform preferences for parcels that provide ecosystemic services, wildlife habitat, viewsheds, local heritage, and agricultural productivity". Kerselaers et al. [55] provide a review of the diversity of criteria that are mentioned to determine farmland preservation priorities. In the case of the Huerta de Valencia, Marques-Perez and Segura [48] stress that integrating people in the decision-making process is fundamental for conveying the preferences of citizens and preventing conflicts.

The literature on rationales therefore highlights a public focus on open space, landscapes and the environment, beyond farming. Mixed policy goals and conflicting interests, both among stakeholders and among farmers themselves, are part of these underlying rationales. The confusion between farmland and farming may be the first barrier to the success of FP programs.

4. Barriers and Challenges for Farmland Protection Programs to be Effective and Take Farming into Account

FP programs' implementation often encounters the same problems: the lack of awareness of how farms and farming systems operate; the lack of adequate enforcement by, and coordination between, public stakeholders; and the failure to take into account the contradictory time frames of the parties involved as well as the specific features of the local context.

4.1. Lack of Awareness of How Peri-Urban Farms and Farming Systems Operate

Preservation and commodity programs may work against one another on the suburban fringe [56].

Agricultural policies, driven in the US by the state and in the Mediterranean by national governments and the European Union (EU) use regulations and incentives to tell farmers what and how to farm. They may be decisive in maintaining farming (e.g., through income support or through direct payments to farmers) in contexts of high external pressure for non-agricultural use of the farmland. However, such policies do not always support peri-urban farms. For instance, Piorr et al. [57] explain that the EU Common Agricultural Policy does not recognize the specific needs of urban and periurban agriculture due to their particular characteristics in terms of actors, scale, diversity and location in urban areas and their surroundings. Urban and peri-urban farms were even excluded from Rural Development Policies until very recently.

Similarly, FP programs sometimes show a lack of awareness of how farms and farming systems work, especially when they are designed by urban stakeholders without sufficient knowledge of

agriculture. Zoning may show spatial inconsistency. When prime productive farmlands are located close to urban areas and face higher pressure, they may be less protected, as in the South of France [58]. In Wisconsin, for instance, exclusive agricultural zoning is more likely to be adopted in municipalities located outside conurbations [59]. Moreover, when strict zoning regulations are imposed on some areas for urban containment (and not for farming purposes), they may increase urbanization pressure and the processes of land speculation in the surrounding farmlands where restrictions are less severe [29,60].

Issues of spatial coherence have also been pointed out in programs of purchase of development rights (PDR). Lynch and Musser [61] showed that preserved parcels were scattered in Maryland. Such programs involve significant tradeoffs between preserving the most productive land (for sustaining the agricultural economy) and annexing the land that is most strategic for growth management policies [62,63]. This is especially significant when priority purchase areas are designated by local governments and/or nonprofit organizations [64]. On the urban fringe, voluntary FP instruments are not always sufficient to preserve the critical mass of farmland needed to sustain an agricultural industry [65]. With regard to achieving this goal, [66] stress the need to consider both the erosion of the farmland base and parcel fragmentation (parcel size and contiguity), because isolated parcels are less likely to remain actively farmed. To justify their public cost, PDR programs still have to demonstrate that they "not only prevent development, but truly help maintain farming" [67].

4.2. Debates on the Impact of FP Programs on Farming on the Urban Fringe

The impact of FP programs on farming has been widely debated. In the 1970s and 1980s, the "impermanence syndrome" was highlighted amongst farmers on the rural/urban fringe, who were reluctant to invest in farming because they expected agricultural decline and urban development [68,69]. Scholars compared alternative tools of FP [42,70]. In the 1990s, scholars underlined the positive effect of FP programs on preserving farming activities. Cases showed that strict regulations help avoid farmland fragmentation [2], while PDR enhances farms' economic viability by providing farmers with funds that can be invested in farm operations [71].

Since 2000, the effects of zoning and conservation easements on agricultural property values have been debated, but results of various econometric studies remain inconclusive [43,72]. Roe et al. [73] showed that preserved farmland provides an amenity for new residents that might attract new development in the surroundings. In their review, Bergstrom and Ready [74] conclude that public willingness to pay for farmland preservation in North America is positively related to farmland acreage, regional farmland scarcity, alternative development intensity, productivity (e.g., soil quality) and active farming, among others, and negatively related to intensive agriculture.

Several studies have examined how farming activity is affected by FP programs. Akimowicz et al. [75] highlight that Ontario's Greenbelt zoning is not sufficient to preserve urban-influenced farming. Lynch and Musser [61] showed that FP programs were most effective in maximizing the number of acres and preserving productive farms, rather than in preserving contiguous farms or threatened farms. Whether preserved farmland is falling out of agricultural use is still debated. FP may lead to a change in the way people farm: some concerns have emerged regarding the diversion of preserved farmland from agriculture to less intensive uses. In Oregon, strict regulations "may inadvertently encourage the growth of hobby farming, potentially at the expense of commercial farming" [38]. Brabec and Smith [66] also note a rise in equestrian pursuits and wildflower meadows taking "land out of traditional agriculture" in areas preserved by conservation easements and clustering programs. However, Gottlieb et al. [76] posit that the negative effect of hobby farming on urban fringe agriculture may be exaggerated: they find no evidence that hobby farmers are disproportionately attracted by voluntary farmland preservation programs and no statistically significant impact from FP on farm investment. For Schilling et al. [77], preserved farmland is even more likely to remain actively farmed. It attracts young farmers and incites owners to have succession plans to transfer the land to an active farmer.

In the Mediterranean, both trends of abandonment and intensification have been observed in peri-urban farmland under land-use regulations. In the hills above Florence, Italy, restrictive zoning

aimed at preserving the historic landscape did not help retain farmers and active farming on the land [78]. Only wealthier landowners still maintain olive trees in their backyards, for aesthetic purposes. On the fringes of Barcelona, Spain, the Baix Llobregat Agricultural Park (BLAP) emerged as a farmers' initiative to preserve their farms and livelihoods [79]. This reinforced-zoning FP device was the impetus for sustainable intensification of existing farming and the development of local alternative food networks. Hence, though FP programs alone are often not enough to maintain active farming, they may be crucial to agricultural projects' success.

4.3. Implementation Challenges Related to Public Action: A Lack of Coordination

The scientific literature on FP reports many implementation issues related to the action of public stakeholders, especially for regulatory land-use planning.

Local authorities' interpretation of the legal framework often leads to spatial variations in the rules. This is mentioned in France [80], England [33], Switzerland [81] or the Netherlands [29]. Some authors further claim government failure. In Israel, Alfasi et al. [32] denounce case-by-case "discretionary-oriented decision-making, providing for revisions of the land-use plans and subsequently diminishing its efficacy", with FP being traded for economic growth. In Portugal, municipal master plans show high levels of non-compliance around Lisbon, mostly at the expense of peri-urban farmland [82]. In Italy, illegal building activities have been favored by the adoption of three building amnesty laws since 1984 [83]. But non-compliance with FP policies is not limited to the Mediterranean region [84]. In the US, Kline et al. [85] also document a "lack of adequate enforcement resulting in improper development mostly in exclusive agricultural use zones" in the Portland-Vancouver area. Since the 1980s, farmland preservation has often been analyzed as "a matter of local politics" [41,86], occasioning pressure on local officials by both development and conservation interests. Thus, it is not surprising that zoning decided at the local level appears to represent a political compromise [87].

To cope with implementation issues, planners and scholars stress the need for better vertical coordination between multiple decision levels [5,88]. Some authors fear negative effects on FP stemming from increased municipal autonomy [29] and believe that the solution lies in a supervisory authority [80,85]. However, Androkovich [24] shows that the supervisory commission which manages the agricultural land reserve of British Columbia, Canada, is also subject to pressure from development interests. The trade-off between restrictive top-down guidelines and local autonomy is still open to debate. In Mediterranean countries, the degree of local independence varies. Jouve and Napoléone [22] found that in 8 countries, local authorities (mainly at the municipal level) formulate their own land-use regulation policies and give building permits within the framework of national planning laws. The main tool used is exclusive agricultural zoning. In France and Italy, the current shift from a top-down management regime to a more decentralized and flexible one has, however, increased the complexity of governance [15]. Local authorities gain a lot of room to maneuver despite abiding by the common national legal framework. In Bavaria, Germany, Artmann [89] points out that flexibility—including informal planning strategies—sometimes acts as a guarantee of high acceptance and thus more effective implementation of FP policies by local authorities. Depending on the local context, local autonomy may thus attract criticism or praise for its potential to generate experimentation and innovation in FP.

Another implementation issue arises from the lack of horizontal coordination between sectoral policies. Farmland on the urban fringe is typically simultaneously at the heart of policies for urban planning, rural development, the environment and agriculture. The literature shows that a lack of intersectoral coordination increases low-density leapfrog urban development and the scattering of buildings related to farming. In Japan, the lack of coordination between the urban and the rural planning systems explains the disordered development patterns and increasing vacant areas in urban fringes [31]. In Switzerland, Gennaio et al. [81] identify conflicting goals and regulations with regard to farmland conservation and construction authorized for agricultural and rural development purposes in the Spatial Planning Law. Similar concerns about farm buildings are raised in other developed countries by Millward [90], Gosnell et al. [38] and Perrin et al. [15].

The Mediterranean is often pointed out as a region with a lack of enforcement of planning policies and a proliferation of illegal building practices. However, the above results underline that such issues occur in most countries.

4.4. Differences in Time Frames and Uncertainty Discourage Farming on the Urban Fringe

Conflicting time frames between long-term preservation programs and short-term individual strategies are additional barriers to maintaining active farming on the urban fringe.

A challenge of time frame adjustment is frequently mentioned for regulatory approaches. Uncertainty, speculation, and contradictory expectations are common within land-use planning processes [91]. Adelaja et al. [92] underline that the length of the planning horizon is directly related to the farm profile: farms with perennial crops, trees, or animals need longer-term planning horizons. In France, the economists Geniaux et al. [93] confirm that landowners' anticipation of agricultural land conversion is one of the key drivers of future development, especially when land-use plans are frequently altered or perceived as subject to change. Around Tokyo, where land prices are high, Yagi and Garrod [94] consider that a preferential taxation system may help farmers with real estate income to retain more of their farmland. Conflicting time frames between landowners' strategies, local authorities' political agenda and urgent urban development projects all create pressures leading to shorter farming leases. This in turn may discourage farming on the urban fringe and long-term farming investment.

Similarly, empirical studies dealing with negotiations on property rights (conservation easements, PDR) are united in stressing the issue of contradictory time frames among the parties and institutions involved. Because such programs are based on voluntary agreements, their efficacy may be weakened by individual landowners' strategies. Extensive literature has examined what motivates landowners to participate [95,96]. Lynch and Lovell [62] found that landowners closer to cities are less likely to participate, as did Comerford [97], who also stated that they are more likely to enroll for land that "they had already set aside for conservation, or land that is less suitable for production". Landowners may believe that placing an easement too soon could cause them to forego potential benefits in the future [98]. However, Towe et al. [99] found that the mere existence of an option to preserve farmland (through PDR) delays decisions to convert farmland for urban development.

4.5. Farmland Protection Policies Must Be Adapted to Local Contexts

The literature highlights the difficulty of assessing the efficacy of various tools and comparing case studies due to differences in social and spatial contexts. In particular, scholars warn against laying out possible causal relationships between land-use planning and land-use change [85]. Many exogenous and endogenous factors influence FP efficacy and land development patterns [100]. Our corpus of reviewed papers reveals three ranges of factors.

The first relates to geographic features such as existing population densities, urban growth patterns and physical land features, or socio-demographic determinants. For example, Altes [101] stresses that a tax on urban sprawl should distinguish between leapfrog and spill-over development patterns. Millward [90] finds more stringent control over urban sprawl in Great Britain and Japan than in Canada, yet puts his own results into perspective by stating that open space is a scarcer resource in the first two countries than in Canada. Previously around the Mediterranean, the typical urban settlement was very compact, with dynamic urban centers and numerous small and medium surrounding towns. But cities of the northern coast have all faced a sprawling expansion [102] while cities of the southern coast experienced more compact urban developments [14,103]. FP programs need to be adapted to such urban patterns.

The second range of factors relates to property rights regimes and land tenure. The right to compensation in the event of regulatory takings differs between countries [104,105]. Private property may be conceived as a bundle of rights or as full ownership. These differences help explain the growing interest in incentive- and market-based tools in the last twenty years in the US, while in Mediterranean countries, public policies

do not usually feature conservation easement programs for FP. Public acquisitions are possible in France, Algeria, Greece or Tunisia, but in full ownership [22]. Also, in most Mediterranean countries, taxes on land ownership are low as the property structure is based on family lands, which are often considered more as a heritage than a production factor. Moreover, on both shores of the Mediterranean, political reforms tend to promote the private appropriation of farmland [14] and reduce the scope of the commons, whereas collective forms of land management prove to be resilient, especially in the case of extensive agro-pastoral systems or in order to promote local food supply chains [106]. The local diversity of land tenure in the Mediterranean has to be considered in FP policies, as well as the absence of comprehensive cadasters and the frequent fragmentation of land holdings or uneven land ownership structure. In Greece, these factors still contribute to the scattering of buildings on farmland, despite the recent implementation of municipal land-use regulations [107]. Farmers' land tenancy also counts: in the south of France and in Italy, land speculation comes from landowners, while tenant farmers will more actively support strict zoning regulations on the urban fringe [78].

The third range of factors relates to the local nature and dynamics of farming systems. Agriculture characteristics—such as relative agricultural profitability, local agricultural organizations, and the image of the agricultural sector—have a significant impact on the adoption of local FP policies [108]. In the French Provence, for instance, organic farming with high profitability appears to be an ally in the preservation of farmland on the urban fringe (*ibid.*). The same argument could be applied to highly profitable peri-urban farming systems based on vegetables or quality grapes growing around many southern European cities. However, FP policies have to acknowledge the diversity—and complexity—of the dynamics of farms in Mediterranean peri-urban settings [109]; the prime farmlands and farmers' requirements in terms of water access, minimum farmland size and collective facilities are not the same for vegetable as for grape growing [78]. The economic and social organization of farming also influences the ability to resist conversion of peri-urban farmland and the adoption of regulatory FP policies, as illustrated by the impressive development of short food supply chains in the agricultural park (BLAP) of Barcelona [79] or by the way a local union of Provençal wine producers successfully defended its *terroir* against urban expansion [110].

Different tools or policies may be needed or prioritized according to the local context. All the cited former barriers to FP, whether related to insufficient awareness concerning farming systems, to inadequate implementation by local authorities, or to the contradictory time frames among stakeholders, confirm that FP cannot rely on merely copy-pasting policy tools that have proved successful elsewhere.

5. Improvement of Farmland Protection Policies and Future Research

Recently identified avenues of improvement should help in designing FP strategies that take local contexts into account. Such strategies include technical innovations in spatial modeling, innovative participatory and collaborative approaches, non-financial means of compensation and combined tools.

5.1. Integrating Social Data into Spatial Modeling

Since 1995, new methods in spatial modeling have been developed. They may be considered revolutionary tools for policy-makers and comparative research. They are usually based on remote sensing, multi-criteria analysis, and Geographic Information Systems (GIS). These approaches address methodological issues identified in previous comparative approaches based mostly on statistical indicators or local maps [100]. They have been used to develop international comparative approaches of land-use changes [102] and to integrate environmental and human variables in strategic farmland characterization maps [109,111].

Policy makers now count on such methods for diagnostic purposes in policy design to identify priority areas for intervention and context-specific public action opportunities [112], to assess FP policy implementation [38,63] with real-time monitoring [31], as well as to build prospective scenarios and sometimes to discuss trade-off options as part of participatory processes. Despite the

sophistication of landscape modeling, scholars today stress the need to integrate more social data into such approaches; for instance, public perceptions and attitudes [113] or stakeholders' values and community knowledge [51]. In the case of the Huerta de Valencia, Marques-Perez and Segura [48] tested one method based on multi-criteria analysis to integrate social preferences for multifunctional peri-urban farming into planning processes. This constitutes an interesting research avenue connecting quantitative and qualitative geography with sociology and planning. Such improved spatial modeling would be especially relevant for some Mediterranean countries in which the state does not produce spatial data on farmland consumption. Specific funding, however, would be necessary to support local researchers' access to such tools and to aerial photos or satellite imagery.

5.2. Involving Farmers and Recognizing Conflicting Points of View in Collaborative and Participatory Processes

Stakeholder-based approaches like collaborative planning and participatory initiatives have become increasingly common when addressing complex policy issues.

However, implementing collaborative and participatory initiatives for FP is complex. The key issue is the diversity of stakeholders. Researchers state a lack of involvement of farmers [114]. The very different types of knowledge held by planners, elected officials and farmers can also make dialogue more difficult [115]. For example, James [116] blames the failure of green zones in Sydney on a lack of consultation with culturally and linguistically diverse small-scale farmers. Considering the role of expertise in FP task forces, Smith Korfmacher and Koontz [117] suggested that professionals work with collaborative groups to determine what information would be useful in the planning process.

Collaborative planning is also difficult because of stakeholders' conflicting points of view. State representatives often advocate urban containment, while local elected officials are often reluctant to counter urban development put forward by interest groups [118]. Another point of divergence relates to the various functions of peri-urban agriculture as defined by different stakeholders (economy, landscape, food, etc.) [37,40]. Around Toulouse (France), as well, Akimowicz et al. [75] stress the need for a better alignment of farmers and other agricultural stakeholders' representations of agriculture. Farmers themselves are not a homogeneous social category. They express diverse and sometimes divergent points of view according to their farming systems, age or land strategy [60,116]. Considering this diversity of farming styles may be another avenue of improvement for FP research and policy [106].

Building a consensus should not mean ignoring these conflicting points of view. It should instead acknowledge stakeholders' perceptions [51] and identify potential value conflicts [30]. Perceptions of injustice are pivotal aspects of land transactions [91]. To avoid the usual resentment toward planning processes, more research is needed on these issues of fairness and social acceptability of FP policies. This also means that planners and researchers could act less as regulators and more as productive mediators to achieve some form of consensus.

5.3. Diversifying Compensation to Improve Social Acceptability

FP issues illustrate how closely intertwined planning, laws and property rights may be. Restrictive zoning impacts property rights, but local negotiations on private rights also raise concerns about financial and non-financial considerations when landowners or tenants waive certain rights. A way to improve social acceptability of FP policies is to diversify types of compensation.

Monetary compensation can be used within collective farming goals, such as supporting land consolidation or collective processing units [30]. Non-monetary types of compensation can be used to overcome contradictory time frames and to avoid conflicting agendas (between local institutions in charge of preservation programs and landowners) and the speculative behavior that increases land prices. In the Netherlands, for instance, landowners are encouraged to demolish vacant buildings, especially empty stables, to improve the overall quality of the landscape. If they do, they receive new building rights [119]. This initiative, called the Space for Space Program, was set up following a European requirement to limit water pollution caused by nitrate emissions from the livestock industry.

It represents a mixed model between the market-oriented programs of rights transfer currently used in the US and the regulatory instruments used in the planning-led European tradition.

In Spain, legal reforms have fostered the use of land readjustment to avoid financial compensation related to expropriations. In the Valencia region, land readjustment was used to create a new neighborhood. Landowners could choose between selling their property or receiving development rights in the adjusted land scheme [120]. The municipality received a portion of the land for infrastructures and public housing. However, such systems may foster urban sprawl. Land readjustment as a bottom-up initiative coordinated by developers may perpetuate local arrangements and prevent the adoption of restrictive planning regulations. Paradoxically, the strongest opponents to such land readjustment schemes turned out to be foreigners owning land in coastal areas, who protested against further urbanization and insufficient compensation. Conflicts arose especially in areas where rural property is very fragmented and where farm buildings were used illegally for residential purposes [121]. When non-financial compensation—a legal instrument initially designed to cope with a specific local issue—becomes a general planning strategy, it does not carry the same procedural guarantees (democratic control) as the more common land-use planning procedures.

Compensation—whether or not financial—should thus be combined with other tools.

5.4. Combining Tools According to the Local Context

While regulatory approaches since the 1960s have remained a topic of scientific interest, there has been a growing focus on incentive-based approaches and market-based instruments over the past twenty years.

These instruments do not work at the same scale in space and time. Zoning regulations protect a large area at limited public cost, but may trigger conflicts with landowners regarding compensation and be subject to renegotiation over time. Conservation easements are increasingly used in countries where zoning is considered a potential regulatory taking. They preserve smaller and not always contiguous areas for much longer periods of time, with some specific drawbacks such as the need to secure landowners' agreement, complexity and heavy implementation costs, etc. [56,62,95,97]. Conservation easements need to be coordinated and targeted at priority funding areas. Consequently, some scholars consider transferable development rights (TDR) as the cheapest way to pursue FP [66]. However, TDR programs are also complex to implement [122].

Thus, many authors conclude with a recommendation that FP tools should be combined. Open space protection policies work better when implemented in combination with compact urbanization strategies [6,118]. TDR and PDR programs can target the same area and reinforce one another in several ways [122]. Land preservation programs (PDR, TDR) can be based on tax incentives. In Lancaster County, Pennsylvania, such tools complement the widespread use of agricultural zoning and urban growth boundaries [65]. Planners and scholars advise combining these types of purchase programs with regional comprehensive land-use planning [71] and supportive zoning [64] for enhanced results.

Most success stories of farmland preservation thus combine tools within a long-term strategy. In the Dutch Green Heart for instance, the "success [of restrictive zoning] can be attributed to its rigidity and clarity, as well as to the use of additional instruments that for example help to purchase land and develop its recreational potential" [29]. However, while combining tools may appear as the soundest solution, stakeholders should remain aware that not all tools can be implemented in every context.

Further research—especially comparing detailed case studies—is thus needed to guide the choice and implementation of mixed-tool FP schemes in local contexts with diversified urban growth patterns, property rights regimes, or farming systems. This should be a fruitful research avenue for geographers working on Mediterranean countries.

6. Conclusions

The aim of this paper was to review the recent literature on the issue of farmland protection in the face of urbanization, with a specific focus on the Mediterranean region. This region is often pointed out

as lacking effective planning policies while struggling with acute challenges related to food security. Yet, the literature underlines that issues related to FP policies are often the same across the world. Hence, our review of FP mechanisms in developed countries may bring valuable insights for more sustainable management of farmland on the urban fringe in the Mediterranean region.

This review highlights that FP cannot rely merely on transferring policy tools that have proven successful elsewhere. It also reveals that farming systems tend to be neglected by FP policies, as these often focus on land rather than on agriculture. FP policies do not always take into account the specific features of the local context and farmers' need for long-term guarantees if they are to invest and develop their activity on the urban fringe. Our review maps several interesting areas of research on the diversity of FP rationales, as well as the barriers and potential avenues for policy improvement. This may be of interest to students and scholars, but also to practitioners, policy makers and local groups looking for innovative, more flexible or locally suited farmland preservation programs.

Twenty years of research and practice have brought a greater understanding of the rationales behind FP. The literature shows that FP is underpinned, supported, and legitimized by disparate political and ethical views, ranging from urban containment and food security to environmentalist and agrarian ideologies. FP is not only motivated by a desire to support farming. Farming may be a means rather than an end in itself, and thus may become a tool to control urban growth and protect the environment and open spaces. These underlying rationales may change over time. They may also advocate for different farming styles (organic or conventional, commercial or hobby farming). Often, such rationales are not explicit because each position (for or against FP, for or against the use of some tools rather than others) is supported by coalitions of heterogeneous stakeholders with mixed interests. Local case studies revealing the underlying motivations and ethics of the stakeholders may suggest policy options that reduce land-use conflicts and help build a shared vision of the value and functions of farmland in the urban fringe. Research on FP rationales is thus a field that deserves renewed attention in sociology or social geography.

We identified recurrent barriers to implementation of FP policies: conflicting rationales, contradictory time frames, and failure to take into account diverse farming systems as well as the local context's unique features. The literature shows that the diversity of stakeholders' sometimes-contradictory perceptions generates resentment towards planning processes and may impede consensus building. However, researchers disagree on the need and the ways to involve local stakeholders and civil society in policy design. Some favor innovative collaborative or participatory approaches. Others stress the recurring risk of lobbying by economic, pro-development or NIMBY interests during implementation. Even when stakeholder participation is viewed as a cornerstone of policy legitimacy and success, researchers find that certain stakeholders, especially farmers, are often excluded from such processes. Farmers may lack the time or the skills to participate effectively in public policy debates. They are often not organized as a coherent social group with homogeneous strategies. Political ecology case studies could be developed to better understand the obstacles in achieving successful dialogue between state or local officials, landowners, developers, farmers, and non-farmer residents—each with their contradictory time frames, disparate ethical views and different types of knowledge.

We proposed further avenues of improvement of FP processes. Scholars should expose value conflicts and issues of fairness, especially in participatory and collaborative approaches. Planners and researchers together could act less as regulators and more as mediators of stakeholder groups to facilitate the coexistence of diverse value systems and agriculture models on the urban fringe and to help identify conflicting opinions before seeking a consensus. This is an opportunity for action-research. Our review also reveals a growing connection between the qualitative literature dealing with local implementation challenges of FP policies and applied literature dealing with land-use change modeling for diagnosis, monitoring, assessment, or prospective purposes. One of the current challenges in this field is to integrate more social data into spatial modeling, but this can only be tackled by interdisciplinary research teams. Finally, our review reveals a growing debate on methods of compensation for FP or urbanization. Here again, critical sociology or social geography approaches

could help unravel the issues of social and spatial justice among various stakeholders, while planners and economists might be more interested in reframing individual compensation within collective goals.

Since the effects of FP programs are incremental and occur over long periods of time, they are difficult to measure. Now that FP policies have been in place for years in several Mediterranean countries, detailed comparative case studies are needed to determine how the toolbox has been adapted to each local context. While more international comparison would be useful—either to examine country-specific characteristics or the use of certain policy tools across various conditions/factors—our review highlights a greater need for more comprehensive interdisciplinary inquiries at the local level in order to reveal how social, spatial, political and economic contexts affect the design and successful implementation of FP policies.

Finally, this review has been centered on planning issues and land policies, but in developed countries, preserving farmland and maintaining farming on the urban fringe are now frequent features of more holistic, cross-sectoral territorial policies in which peri-urban agriculture is valued as multifunctional and as a provider of ecosystemic services and public goods [57]. Research is still needed to understand how these new framings (for instance through urban food strategies [123,124], agro-ecosystems [20] or productive landscapes [125]), may help to design innovative planning instruments, more in line with the emerging needs of urban and peri-urban farmers, as well as city dwellers.

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Farmland Preservation and Urban Expansion: Case Study of Southern Ontario, Canada

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Farmland is an essential resource for the sustainability and security of human food systems. Preserving an agricultural land base is critical, as it is significantly affected by local, national, and global urbanization. This research introduces a case of farmland preservation in southern Ontario. This area contains some of Canada's most finite and productive soils but has an agricultural system facing enormous pressure from urban expansion. This paper reviews the farmland preservation policy framework within Ontario and provides insight into the role of different levels of government in protecting this critical resource. It also provides data at a regional level that provides the basis to evaluate the success of provincial and local policies. By tracking agricultural land conversion through local Official Plan Amendments (OPAs), this study documents farmland loss across southern Ontario between 2000 and 2017. Implemented and approved by local government and designed with public input, municipal Official Plans outline and describe land-use planning policies on how municipalities should use lands to meet community needs and desires. OPAs are formal and legally binding administrative changes to a municipal Official Plan decided through an open public process, which are required to change local land-use designations that conform with the long-term vision for growth and physical development. These OPAs may include the conversion of farmlands for non-farm uses (or, in contrast, the protection of agricultural lands). Over time, they will reveal the loss of farmlands in each community for different uses (and reflect changing priorities). Using OPAs to track the conversion of prime agricultural land is an innovative and rigorous methodological contribution, given the lack of data documenting long-term changes to the availability of agricultural lands and the impacts of urbanization on farmland conversion. Measuring farmland loss with this approach can be transferred and applied to contexts where municipalities are the entities responsible for agricultural land-use planning, outside of Ontario and beyond. Data from 36 counties/regions shows that the provincial policies and local planning framework have worked in tandem to affect the agricultural land base in southern Ontario significantly. In Central Ontario, the most urbanized area of Canada, the Province's Greenbelt Plan has significantly reduced the rates of farmland loss since 2005, while the Growth Plan and other policies contributed to enhanced municipal control over agricultural land conversion. Specifically, the Inner Ring municipalities have played increasingly active roles in agricultural land protection

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with both planning approaches and local initiatives. Outer Ring municipalities have seen increasing urbanization pressure. Data on farmland loss for non-agricultural use showed large-scale municipal-led urban boundary expansions and small-scale individual applications on policy changes. In Western Ontario, over the past two decades, there has been no obvious upward or downward trend of farmland loss. Most of the farmland conversion cases in this region were small-scale applications to create small lots on existing agricultural land to allow non-agricultural uses such as commercial, recreational, residential, and agricultural-related facilities. Since 2000, Southeastern Ontario, which has the smallest provincial share of prime agricultural land, has experienced limited farmland loss, consisting primarily of small-scale, individual applications on land-use re-designations (partially reflecting reduced acreages of prime agricultural land). The provincial policy impact on farmland preservation is not as evident in this region. The findings and methodology of this study contribute to the groundwork on farmland availability and land-use planning policy development and research by providing a baseline enumeration of farmland availability and the effect of farmland protection policies at provincial and municipal levels within Ontario's land use planning regime.

Keywords: farmland loss, preservation, urban expansion, Greenbelt, land use policy, Ontario

INTRODUCTION

Farmland is an essential resource for the sustainability and security of human food systems, environments, agricultural industries, and livelihoods. Beyond the provisioning value and services of farmland, such as with food and fiber, sustainably managed farmland provides several other invaluable ecosystem services, such as pollinator and wildlife habitat, carbon sequestration, nutrient cycling, water regulation, as well as amenity value (Power, 2010). However, the capacity of farmland and agricultural industries to provide these services beneficial to collective wellbeing depends on the availability and quality of farmland available (Barral et al., 2015; Hu et al., 2018; Benton et al., 2021).

Due to global urbanization, farmland availability has been increasingly under threat from social, physical, and climate factors (Hertel, 2011; Vinge, 2018). Preserving agricultural land for current and future generations is a worldwide topic that must be addressed urgently (Hertel, 2011; Caldwell et al., 2017; FAO, 2021). Research on the threats of urbanization on farmland resources specifically is of global priority and is evident in Canada (Qiu et al., 2015; Epp and Caldwell, 2018; Connell, 2020; Cameron and Connell, 2021), the United States (Moroney and Castellano, 2018; Narducci et al., 2019), Europe (Tan et al., 2009; Perrin, 2013; Skog and Steinnes, 2016), and China (Chien, 2015; Zhang et al., 2016; Hu et al., 2018; Duan et al., 2021; Miao et al., 2021). There is a need to address complex drivers contributing to farmland loss as well as diminishing physical capacity of lands to support climate change mitigation and adaptation measures (Masson-Delmotte et al., 2021). Agricultural and urban anthropogenic land uses have already partially converted an estimated 43% of global land area (Barnosky et al., 2011), having significant implications for the land base fragmentation, biodiversity loss, ecological health, and climate resilience (Laurance et al., 2014; Capmourteres et al., 2018). Additionally, once farmland is lost to urban development, its productive capability is lost forever (Moroney and Castellano, 2018). Thus, preserving and protecting existing agricultural land resources is critical for the future resilience and sustainability of food systems, communities, and agricultural economies.

Canada has a robust agricultural sector with over $100 billion annual GDP and 2.3 million jobs in agriculture and agri-food (Agriculture and Agri-Food Canada, 2019). Nevertheless, farmland is a limited resource in Canada, and only occupies 7.3% of the land area due to soil quality, climate, and terrain restrictions (Statistics Canada, 2014). Much of the most productive agricultural soils are located within Ontario, both the most populated part of Canada and where most farmland loss occurs nationally (Statistics Canada, 2016). Census data shows that total farmland in Ontario has fallen by 50% since 1941. Additionally, over 1.5 million acres of farmland were lost between 1996 and 2016 (Ontario Ministry of Agriculture, 2017). Like many fast-developing regions worldwide, urban sprawl has consumed large tracts of agricultural soils in Ontario during the past few decades. Urbanization is unlikely to slow down: the population in Ontario is projected to grow to over 20 million by 2046, representing a 35.8% increase from 2020 (Government of Ontario, 2022). Moreover, the fragmentation of the agricultural land base and the imposition of low-density urban sprawl into agricultural communities often poses challenges for agricultural viability and compatibility for farmers and non-farmers alike (Qiu et al., 2015; Epp and Caldwell, 2018).

Relative to the rest of the province, southern Ontario contains some of Canada's most finite and productive soils (Agriculture and Agri-Food Canada, 2019). The Canada Land Inventory (CLI) is used to designate land based on soil type, giving the land a numerical designation based on agricultural suitability (in terms of crop production). The CLI consists of seven distinct classes of

agricultural land based on its productive potential, with classes 1, 2, and 3 soils considered to be "prime agricultural land." By contrast, categories above soil classification 3 are deemed limited in their productive capability. Only 0.5% of Canada's total land base comprises Class 1 land (which is the highest quality in soil classification), and most of this soil is in southern Ontario (Walton, 2003; Caldwell et al., 2017). Since most of the future urban development is expected to occur in this region, farmland protection is vital for southern Ontario (Office of the Auditor General of Ontario, 2021).

While movements, programs, and policies to protect farmland from urbanization across North America have been implemented since the 1950s (Bunce, 1998), there is much to learn about the effectiveness of farmland protection policies (Liu and Lynch, 2011; Connell, 2020). For example, since 2005, the Ontario provincial government has established a series of policies to regulate urban sprawl and strengthen farmland protection, including the Provincial Policy Statement (MMAH, 2005c, 2014), the Greenbelt Plan (MMAH, 2005b), and the Growth Plan (MMAH, 2005a). Collectively, these plans establish a provincial land-use planning framework to identify policies for where urbanization should *not* occur to protect ecological features such as farmland, and guide transit-oriented development, intensification, and densification to already urbanized communities. These provincial plans are then interpreted and implemented at the municipal level, leaving room for variability in their interpretation and application of policies amongst local communities. Since establishing these policies, little research has evaluated farmland loss in southern Ontario to test their effectiveness in preserving farmland. This absence of evaluation is despite Ontario's farmland protection policies being internationally recognized for its success (see Government of Ontario, 2007) and establishing one of the most extensive greenbelts in the world (Carter-Whitney, 2008). This article attempts to provide a comprehensive provincial-wide assessment of one of the world's largest geographically protected farmland areas (Carter-Whitney, 2008), building off a study exploring farmland loss in two Ontario municipalities from Epp and Caldwell (2018). This study also contributes to the larger body of literature evaluating the effectiveness of farmland protection policies around the globe (Connell, 2020).

While the Canadian Census of Agriculture quantifies the amount of agricultural land in production, it lacks documentation of land-use planning decisions (i.e., non-farm and urban development), compromising the preservation of prime agricultural lands. This research fills this gap from a land-use planning perspective, for which the methodological framework can be applied in other municipal jurisdictions responsible for agricultural planning but have yet to officially account for the preventative loss of this vital resource (Robert and Mullinix, 2018; Connell, 2020; Cameron and Connell, 2021). An innovative approach to measuring farmland loss is introduced by tracking agricultural land conversion in municipal Official Plan Amendments across southern Ontario municipalities. OPAs are legally binding municipally-led administrative decisions to change a municipal Official Plan, which are required to redesignate lands to different uses so that new proposed uses may conform with the municipality's long-term vision for growth and physical development. In turn, OPAs reflect the potential loss of farmland and change in community development priorities over time. This approach provides a more comprehensive, accurate, and reliable picture of the state of farmland loss in Ontario by measuring the amount of converted farmland to non-agricultural uses when the land-use planning decision was made (Epp and Caldwell, 2018). The reliability of this method is relative to what could be inferred from the Canadian Census of Agriculture, or other methods of measuring farmland loss, such as land cover map comparisons (Chen et al., 2016; Song and Liu, 2017), plan quality evaluation (Connell, 2020; Cameron and Connell, 2021), GIS analysis and remote sensing (Qiu et al., 2015; Skog and Steinnes, 2016; Hu et al., 2018; Duan et al., 2021), propensity score matching (Liu and Lynch, 2011), econometric modeling (Qiu et al., 2015; Xu et al., 2019; Miao et al., 2021), statistical analysis of census data (Epp and Caldwell, 2018; Moroney and Castellano, 2018), and qualitative analysis of archival records and anecdotal accounts (Perrin, 2013; Cameron and Connell, 2021). The analysis of OPAs thus reveals how provincial policies shaped farmland loss at a regional scale between 2000 and 2017. Tracking the decisions made during this time frame reflects how municipalities may vary in their interpretation and implementation of the provincial land-use planning framework, inclusive of plans such as the Provincial Policy Statement, Growth Plan for the Greater Golden Horseshoe, and the Greenbelt Plan.

BACKGROUND AND CONTEXT

This next section will review the context for the research, providing some background into the legislative and policy-setting justifying land-use planning and farmland preservation in Ontario. This section will then provide an overview of the study area, including geography, development characteristics of various regions, and land area.

Agricultural Land-Use Planning and Legislative Basis for Farmland Protection in Ontario

A hierarchical planning system regulates agricultural land in Ontario. This means that the provincial government sets up the overall policy framework, which applies to various regions across the province. Municipal policies must meet the requirements of consistency and abide by provincial and regional regulations, plans, and policies in their local planning decisions. However, local-level interpretation and implementation of provincial planning policies will vary by municipality. This system promotes a coordinated planning system that achieves "good planning" that recognizes specific provincial interests (e.g., growth management and farmland protection) while allowing local governments to translate policies and make decisions to fit their local needs, desires, and contexts. As a result, decisions around agricultural land uses will vary at municipal levels despite provincially implemented farmland protection policies.

The Provincial Policy Statement (PPS) establishes the provincial interest in planning across the province, and municipal planning decisions must be consistent with this document. It lays out the vision for Ontario's long-term agricultural land protection and specifies conditions under which agricultural land can be converted to non-agricultural uses. Municipalities have the authority to create their own Official Plans. In doing so, municipalities can establish their local agricultural land designation system, specify local agricultural land-use policies, and map out the designated agricultural land under the authority of the provincial Planning Act (1990). Official Plans serve as a guiding document that outlines the community's vision and designates land for a variety of uses. Any change in agricultural land designations must go through the municipal government's approval and be finalized *via* Official Plan Amendments (OPAs).

The Greater Golden Horseshoe (GGH) is Canada's and Ontario's most urbanized region. The GGH is currently home to an estimated 10.2 million residents in just 3% of Ontario's land area (Office of the Auditor General of Ontario, 2021). Regarding economic significance to Ontario, the GGH alone contributes two-thirds of provincial gross domestic product (GDP) and one-quarter of Canada's annual GDP (Allen et al., 2015). Concurrently, some of Canada's finite, most productive agricultural lands and ecologically sensitive features, such as the Greenbelt, Oak Ridges Moraine, and Niagara Escarpment, are found in this part of southern Ontario. As a result, the GGH is an economic powerhouse and asset for agriculture and agri-food industries in Ontario. For example, 40% of GGH land area is quality productive farmland, and the regional agriculture industry contributes supports 38,000 jobs and one-third of Ontario's agri-food industry area (Office of the Auditor General of Ontario, 2021). Despite the value of these finite agricultural resources and agri-food networks, this provincial resource base has historically been threatened by "scattered" low-density development and urbanization. This growth pattern has led to farmland loss and the subsequent loss of ecosystem services that the agricultural resources and ecological features provide (MMAH, 2005a). For instance, from 1996 to 2021, the GGH's population increased by 57%, with the provincial government forecasting an additional 45% increase (to 14.8 million residents) by 2051 (Office of the Auditor General of Ontario, 2021). This unprecedented rapid growth and urbanization in southern Ontario have emphasized the need for effective land-use planning policies and measures to prevent adverse outcomes from unchecked growth in the region and prevent sprawling development from spilling outwards of the highly-desirable GGH to the rest of southern Ontario's prime agricultural areas.

In 2005, the provincial government undertook several initiatives to strengthen their response to urban sprawl across Ontario (Macdonald and Keil, 2012). Legislation and policies were issued in tandem to guide urban intensification and agricultural resource protection in southern Ontario. Agricultural lands were given a greater level of protection with a more comprehensive regional governance approach. The 2005 version of the PPS directed those prime agricultural areas be protected for long-term agriculture with certain exceptions for settlement boundary expansions, mineral and petroleum resource extraction, and limited non-residential uses given there are no suitable alternative locations. The 2005 version of the PPS also included the concept of specialty crop areas, mandating planning authorities to designate these areas and giving them the highest priority for protection. In 2014, the Government of Ontario updated the PPS to provide further guidelines for identifying, designating, and protecting prime agricultural land within Official Plans. The province also introduced stricter policies for settlement area expansions into prime agricultural areas. These updates mandated that in addition to the policies outlined in earlier PPS documents, identification and expansion of settlement areas may only occur at the time of a Municipal Comprehensive Review (MCR).

In addition to the changes to the PPS, the *Greenbelt Act*, established in 2005, provided a legislative foundation to create a 7,200 km^2 permanently protected "greenbelt area" in the Greater Golden Horseshoe and gave agricultural land further protection. The Greenbelt Act established a *Greenbelt Plan* in June 2005, which the provincial government subsequently updated in 2017. This continuous and permanent land base secured by the Greenbelt intends to support long-term agricultural production in the Greater Golden Horseshoe area. According to the Greenbelt Act, the Greenbelt Plan prevails, and local Official Plans and zoning by-laws within the protected countryside must be amended to conform with the Greenbelt Plan. Prime agricultural lands were given the following protection by the Greenbelt Plan (MMAH, 2017b):

> *"Prime agricultural land in the 'protected countryside' will be protected 'by preventing further fragmentation and loss of the agricultural land base caused by lot creation and the re-designation of prime agricultural areas; (section 1 (c))."*

Any municipality with land designated "protected countryside" by the Greenbelt Plan was required to identify such areas within their Official Plan. Agricultural land outside of the jurisdiction of the Greenbelt Plan would be designated as agricultural, but land-use protections would vary (reflecting the PPS or other provincial plans). An exception was provided through Policy 3.4.4. for settlement area expansion proposals that had been initiated prior to the implementation of the Greenbelt Plan. In these cases, settlement area expansions may be permitted into prime agricultural areas (MMAH, 2005a).

Two other provincial plans should be noted as they may have overlapping boundaries within the Greenbelt Plan area: the Oak Ridges Moraine Conservation Plan (ORMCP) (MMAH, 2017a) and the Niagara Escarpment Plan (NEP) (Ontario Ministry of Northern Development, Mines and Natural Resources and Forestry, 2017). The ORMCP and NEP tend to be focused on significant ecological and environmental features. In this context, the differing plans need to be interpreted for consistency where they overlap, as natural heritage protection can potentially conflict with agricultural viability.

Apart from the conservation plans noted above, the Places to Grow Act (2005a) and the Growth Plan for the Greater Golden Horseshoe (established in 2006 and updated in 2017;

TABLE 1 | Policies relevant to agricultural land protection in Ontario.

Plan/policy	Priority
Provincial Policy Statement	Protect agricultural resource for long-term use
Oak Ridge Moraine Plan	Protect the ecological integrity and continuity of Oak Ridge Moraine
Niagara Escarpment Plan	Protect the ecological integrity and continuity of Niagara Escarpment
Greenbelt Plan	Protect farmland, communities, forests, wetlands, watersheds, preserves cultural heritage
Growth Plan	Growth management in the GGH area

hereby referred to as the "Growth Plan") also indirectly support agricultural land protection by regulating urban boundary expansion, setting urban intensification targets, and encouraging more compact and mixed-use development (**Table 1**).

Study Area

This research covers 36 municipalities across southern Ontario (**Figure 1**) and the following analysis divides them into three geographic regions, including Central Ontario, Southwestern Ontario, and Southeastern Ontario.

The Central Ontario boundaries were selected in accordance with the Greater Golden Horseshoe. There were 15 municipalities in this area, including Dufferin, Durham, Niagara, Haldimand, Brant, Hamilton, Halton, Waterloo, Wellington, Peel, York, Simcoe, Kawartha Lakes, Peterborough, and Northumberland.[1]. This Central region reported 1,472,687 hectares of census farmland in 2016, 29.5% of the provincial total. Municipalities in this region are further divided into two groups, an "Inner Ring" and "Outer Ring," according to where they are located around the Greenbelt; a provincially protected area comprised of prime agricultural land and environmentally sensitive landscapes.

The "Inner Ring" area covers the municipalities closest to the City of Toronto, including the Regions of Durham, York, Peel, Halton, Niagara, and the City of Hamilton. This area is the most populated metropolitan area in southern Ontario and is under the greatest pressure from urban expansion. It contains 28.8% of the total census farmland in Central Ontario. The "Outer Ring" area refers to municipalities further removed from Toronto, including the Counties/Cities of Dufferin, Haldimand, Brant, Waterloo, Wellington, Simcoe, Kawartha Lakes, Peterborough, and Northumberland. This area includes 72.2% of the census farmland area in Central Ontario.

Most of the municipalities in this region are rural areas with a varied landscape of small and mid-sized cities, towns, villages, and hamlets. Southwestern Ontario comprises 11 municipalities, including Grey, Bruce, Huron, Perth, Oxford, Norfolk, Middlesex, Elgin, Lambton, Chatham-Kent, and Essex. The 2016 Canadian Census of Agriculture reported 2,135,538 hectares of census farmland in this region, 42.7% of the province's total census farm area. The Southeastern Ontario area covers ten municipalities, including Hastings, Prince Edward, Lennox and Addington, Frontenac, Renfrew, Lanark, Leeds and Grenville, Ottawa, Stormont, Dundas and Glengarry, and Prescott and Russell. The total census farm area was 1,014,968 hectares in 2016, which is 20.3% of the provincial census area of farms.

[1]The City of Toronto is excluded from this project because no significant undeveloped prime agricultural land is in its jurisdictional boundary.

METHODOLOGY

This next section will outline, in detail, the methodological framework undertaken inclusive of secondary data collection and analysis procedures, as well as the approach of the methodology adopted and its contributions to the fields of agricultural land-use planning (and preservation) and more specifically, plan evaluation.

The Canadian Census of Agriculture is the primary data source for measuring farmland availability in this research context. The Canadian Census of Agriculture, facilitated at the federal level by Statistics Canada, is conducted every 5 years to collect data related to physical, economic, social, and environmental characteristics of Canadian agricultural industries, farm operators, and farm operations (Statistics Canada, 2021). While the census provides an enumeration of agricultural land in production at different geographic levels, it does not reflect local land-use planning decisions compromising the long-term preservation of these lands, nor does it distinguish between other classes of agricultural land productivity (i.e., prime vs. non-prime). When farmland is redesignated to non-agricultural land uses, on-site farming activities may continue, but these lands are eventually destined for conversion to non-farm uses (Epp and Caldwell, 2018). The census only tracks changes to land production; farms that have been redesignated for urban development but continue agricultural production would be counted in the census regardless of the land-use designation. The census would not capture farmland availability and, potentially, farmland under threat of development. As a result, the use of OPAs would provide a more accurate and valid measure of farmland availability.

This article tracks land-use planning decisions that convert agricultural land to other uses. Municipal OPAs were used as the primary data source to track farmland conversions. These amendments reflect a marked decision to permit the land to be used for an alternative, often development-driven purpose. This methodology responds to the gaps in quality data (specifically the census), documenting the change in farmland availability and the current impacts of non-farm and urban development contributing to long-term trends of farmland conversion. The resulting data provides insight into land-use changes as they occur before development and ultimately assesses the effectiveness of existing policy planning tools in their ability to preserve agricultural lands for the long term in Ontario. Overall, the method is valuable for evaluating policy effectiveness in real-time, in contrast to waiting for census results accounting for the loss of farmland after it has already occurred.

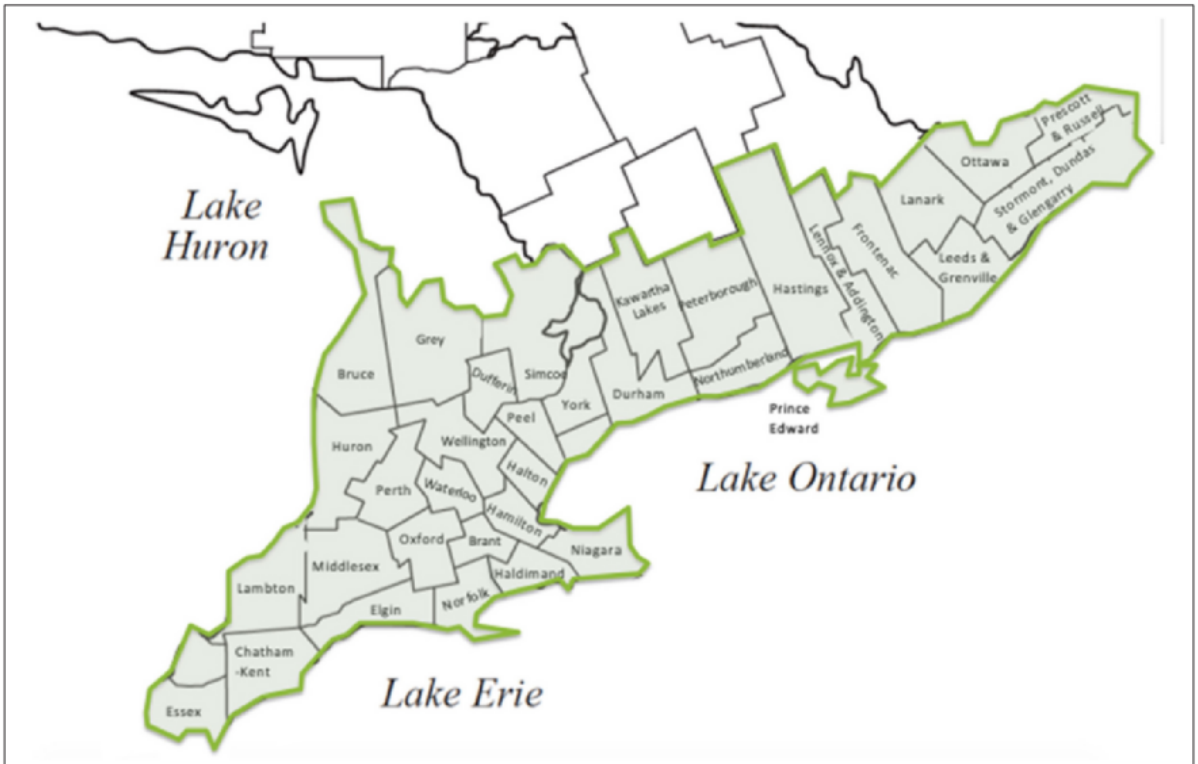

FIGURE 1 | Map of the Southern Ontario.

OPAs provide a consistent, valid, reliable, and publicly available source of data that can be used to track the conversion of prime agricultural land in Ontario reliably and at individual municipal levels, given as they are required by all municipalities when altering land-use designations [Drake, 2019; MMAH, 2021]. In adopting the following methodological process, this article quantifies the Greenbelt Plan's (MMAH, 2005b) effect and measures farmland loss in individual municipal plans in a given timeframe (2000–2017). This methodology has value applied to contexts in Canada and elsewhere, particularly municipal governments responsible for land-use planning, policy implementation, and decision-making. Measuring approvals at this level can help describe prominent regional trends, successes, and failures in managing growth.

The methodological process includes location analysis, boundary identification, and data collection. The first step was to determine where prime agricultural land existed in Ontario to determine the focus areas for the study. Information was drawn from various sources including the Ontario Ministry of Agriculture, Food and Rural Affairs' Agricultural Information Atlas soil capability for agricultural mapping layer.[2] Thirty-six counties and regions with prime agricultural land were identified. The Official Plans of these selected municipalities were reviewed to determine what designations applied to prime agricultural land and any distinction between prime and non-prime agricultural land areas. Researchers collected the data in partnership with municipalities or independently through online databases. As a governance mechanism that mandates reporting, OPAs exist and are publicly available as prescribed by ministerial regulation under the Planning Act (1990), which outlines legislative requirements for the land-use planning process and decision-making in Ontario. As a result, OPAs are a mechanism and application required when a proposed use or development conflicts with a municipal Official Plan and requires an amendment to ensure plan conformity, which is subject to a public hearing process and is approved at the discretion of the municipal council. The primary data collected for this study is taken directly from OPAs approved at the upper-tier (i.e., region or county) level during the study's timeframe. Where available, secondary data including information from the accompanying planner's report, initial OPA application forms, archived municipal council minutes, and Ontario Municipal Board (OMB) case decisions were also used. Additional information collected included: application date, adoption date, OPA purpose, previous land-use designation, new land-use designation, special policy (if applicable), impacted area

[2]http://www.omafra.gov.on.ca/english/landuse/gis/portal.htm

TABLE 2 | Categorization of OPAs in the research study.

No.	Category type	Examples of converted uses
1	Prime agricultural areas redesignated to a development designation.	To permit residential, commercial, industrial, and infrastructural uses. This includes OPAs connected to Municipal Comprehensive Reviews and urban boundary adjustments.
2	Prime agricultural areas redesignated to a rural designation.	Rural designations to permit non-agricultural uses (e.g., village or hamlet).
3	Land designated as a prime agricultural area with a site-specific policy amendment to allow for additional, non-agricultural uses.	Site-specific policies permitting non-agricultural uses on either a portion of the land or the entire parcel, with some of the land remaining in agricultural production (such as on-farm diversified uses).

in hectares, lot and concession plan, other location identifiers and, if applicable, OMB appeals.

Applicable OPAs were categorized into three themes to illustrate and quantify the scales and community development patterns contributing to farmland loss. These categories represent the nature of the amendment. Redesignations to development tended to lead to direct urban expansion (often large-scale farmland conversion); redesignations to rural tended to occur on areas of lesser quality farmland, and the uses tended to be more "rural" (relating to villages and or hamlets). Lastly, site-specific policy amendments tended to be used where the land was still designated as "agriculture." Still, the actual uses, while extensive, were not agricultural (e.g., an automotive speedway on an agricultural parcel). Applicable OPAs were organized into three categories:

1) Prime agricultural areas redesignated to a development designation;
2) Prime agricultural areas redesignated to a rural designation; and
3) Land designated as a prime agricultural area with a site-specific policy amendment to allow additional uses.[3]

These categories and examples of their respective development designations converted from prime agricultural areas are described in further detail in **Table 2**.

FARMLAND LOSS BETWEEN 2000 AND 2017

This next section will outline research results, including various trends relative to farmland loss from 2000 to 2017. First, it will outline trends of farmland loss at a provincial level, followed by region-specific trends related to Central Ontario, Southwestern Ontario, and Southeastern Ontario.

Trends of Farmland Loss at the Provincial Level

Between 2000 and 2017, 545 OPAs were approved to convert prime agricultural land to non-agricultural designations or to permit non-agricultural uses in southern Ontario. In total, these amendments affected 29,217 hectares of designated prime agricultural land. The most prime agricultural land loss occurred in Central Ontario, representing 83.5% of the provincial total (24,404 ha). Comparatively, Central Ontario also experienced the highest population growth[4]. during the past two decades. Southwestern Ontario, which has the greatest farmland area among the three regions, captured 12.1% of the total prime agricultural land loss (3,541 ha). Southeastern Ontario saw the smallest amount of farmland loss among the three areas, with 4.4% of the total captured amount (1,272 ha).

Most prime agricultural land loss identified in this research is captured in the category of "prime agricultural areas redesignated to a development designation," (76%) resulting from large-scale urban boundary expansions, followed by redesignation to rural uses (14%), and site-specific policies allowing for non-agricultural uses (12%) (see **Chart 1**).

The years of 2006, 2013 and 2015 saw the highest amount of prime agricultural land loss due to urban boundary expansion OPAs in the GGH area (**Chart 2**). The most increased annual occurrence of prime agricultural land loss transpired in 2006, with 5,325 hectares of designated prime agricultural land converted. This loss was mainly accounted for by York Region (1,696 ha) and Peel Region (2,428 ha). Another peak of farmland loss was in 2013, which lost 4,388 hectares of prime agricultural land, mainly in Halton Region (2,656 ha) Durham Region (1,562 ha). Similarly, 2015 had the third-highest annual loss of prime agricultural lands, consisting of 1,966 hectares, mainly in York Region (1,000 ha) and Peterborough (688 ha). Most of these large-scale OPAs were part of local MCRs.

In a 5-year incremental timeline (**Figure 2**), the period between 2000 and 2004 (before the establishment of provincial policies) saw a total of 6,172 hectares of prime agricultural land lost, including that in Central Ontario (5,573 ha), Southwestern Ontario (522 ha), and Southeastern Ontario (77 ha).

The period between 2005 and 2009 experienced the greatest amount (11,651 ha) of prime agricultural land loss in all three regions: Central Ontario (8,980 ha), Southwestern Ontario (1,696 ha), and Southeastern Ontario (975 ha). It is important to note that this increase of farmland loss is not "caused" by the 2005 provincial policies, but rather that the extent of farmland loss in this phase is a consequence of applications approved before the Provincial Policy Statement and the Greenbelt Plan came into effect.

The period between 2010 and 2014 better reflects the effect of the 2005 provincial policies, as most of the OPAs

[3]Some types of OPAs were not included in this study. Certain classes of "housekeeping amendments" were excluded, as were OPAs relating to wind turbines and aggregate operations, as they were not considered a permanent land-use conversion in the existing planning system. The timeframe for this study covers 2000–2017. Much of the data pivots around 2005 when revised provincial policy and new legislation were adopted. It, therefore, provides comparative data to assess the strength of these policies.

[4]https://www150.statcan.gc.ca/n1/daily-quotidien/200213/dq200213a-eng.htm

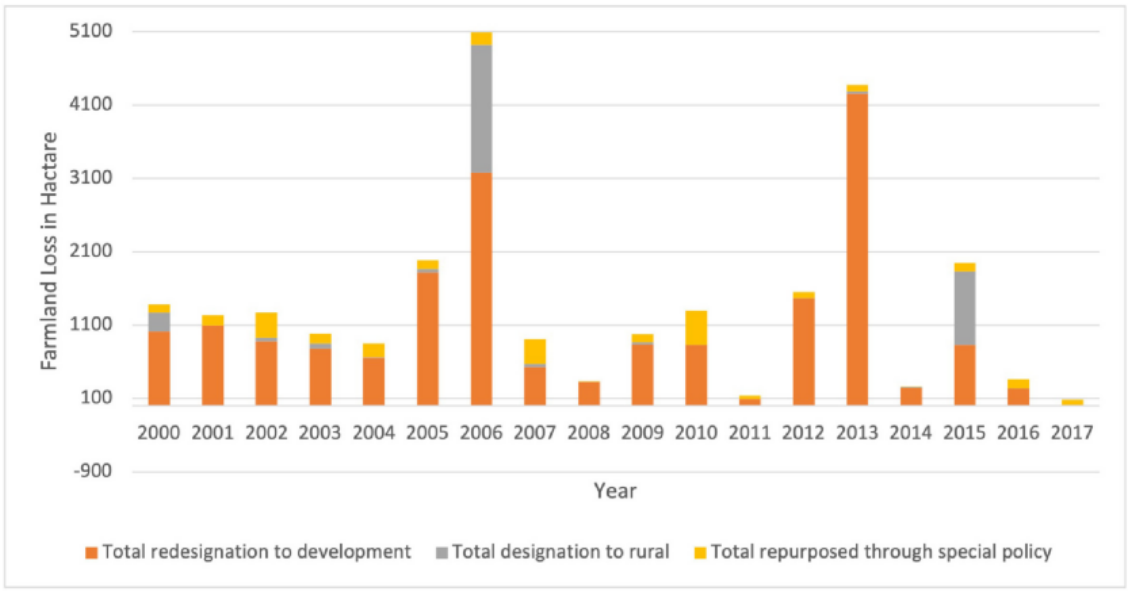

Chart 1 | Yearly prime agricultural land loss divided by category in Southern Ontario, 2000–2017.

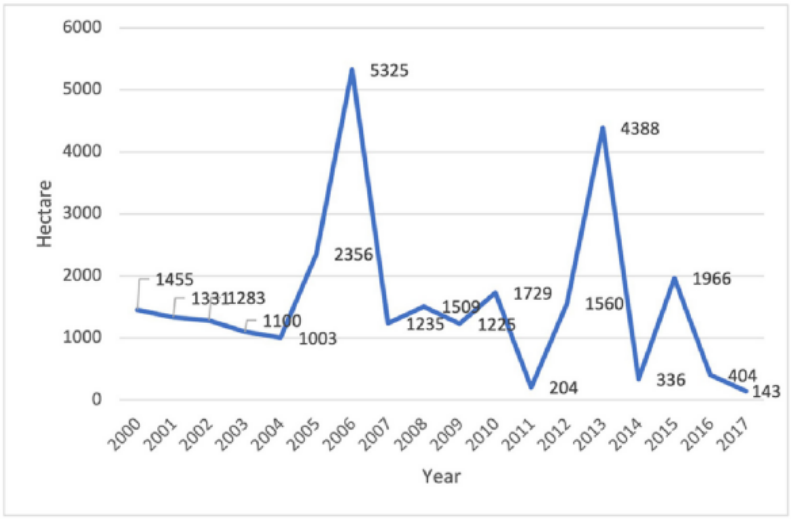

Chart 2 | Agricultural land loss across Southern Ontario by year, 2000–2017.

approved in this phase were subjected to provincial policies' regulation after 2005. All three regions experienced an apparent decline in prime agricultural land loss from 2010 to 2014 (total of 8,216 ha) relative to the farmland lost from 2005 to 2009.

Central Ontario

The Central Ontario region, or the Greater Golden Horseshoe area, is the most urbanized and fastest-developing area. Currently, Central Ontario is under the directive regulation of the Growth Plan and the Greenbelt Plan, with over 90% of the

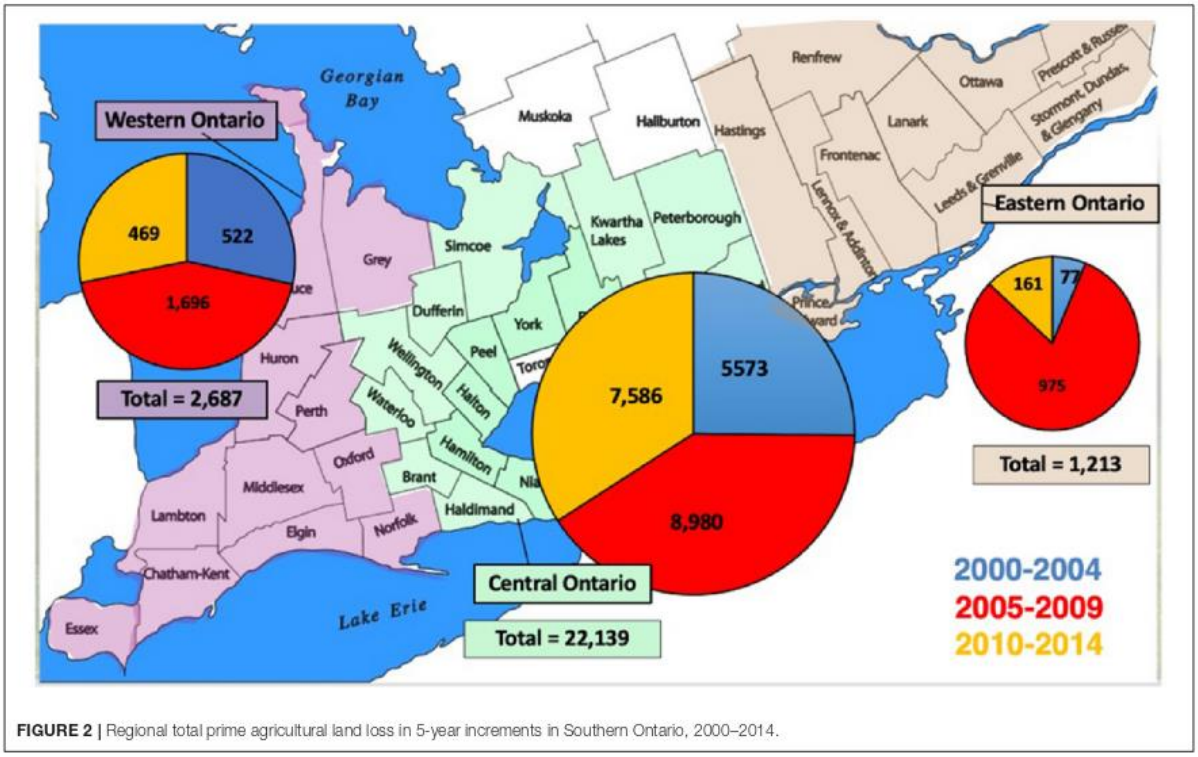

FIGURE 2 | Regional total prime agricultural land loss in 5-year increments in Southern Ontario, 2000–2014.

Greenbelt Plan area and 25 urban growth centers identified in the Growth Plan located within its boundary.

Between 2000 and 2017, Central Ontario captured 83.5% of the total prime agricultural land loss identified in this article and 1.7% of the census farmland area. The three counties/regions which have experienced the highest percentage of prime agricultural land loss are all in the Greater Toronto Area (GTA), including York, Peel, and Halton (**Table 3**).

This article found an overall downward trend in the number of approved OPAs relevant to prime agricultural land loss in Central Ontario from 2000 to 2017 (**Chart 3**). The number of OPAs and their average size demonstrate three different patterns of farmland loss in this region. First is that the most populated GTA municipalities have comparatively fewer OPA numbers and larger average sizes (>200 ha). The fast-developing Outer Ring population centers have comparatively medium OPA numbers and average OPA size (30–60 ha). The other rural Outer Ring counties have a relatively small average OPA size, and they vary in the total number of OPAs.

Most OPAs redesignating prime agricultural land to non-agricultural land uses resulted from MCRs (72%), namely to expand urban boundaries or redesignate farmland for comprehensive urban uses (**Table 4**). Additional purposes for OPAs resulting in farmland loss (**Table 4**) include redesignations to employment lands (10%), recreational, residential, and municipal infrastructural (4%), and other uses, including industrial, commercial, and institutional (5–6%).

Between 2000 and 2017, most of the farmland loss occurred in the Inner Ring area (337 ha lost), accounting for 75% of the total lost farmland in Central Ontario (**Table 5**). Land redesignated for development totaled 13,860 hectares within the Inner Ring (3,052 ha for rural purposes and 1,426 for site-specific non-agricultural uses). During this period, the Outer Ring lost 6,072 hectares. The number of OPAs in the Outer Ring is 50% higher than the Inner Ring; however, the average OPA size is distinctly less (38.9 ha) than the Inner Ring (176.3 ha). **Table 5** illustrates these trends in further detail.

Southwestern Ontario

Southwestern Ontario is a traditionally agricultural region with the greatest provincial share of farmland. The Growth Plan does not apply here, and only a small part of Grey and Bruce Counties falls under the protection of the Greenbelt Plan. There are three major population centers in this region (London, Windsor, and Sarnia); however, urban development in this region has been relatively limited over the past decade. Between 2000 and 2017, this region saw 3,541 hectares of prime agricultural land converted to non-farm uses, representing 12% of the total farmland loss in this research (**Table 6**). The total number of relevant OPAs captured in Southwestern Ontario is 246 and accounts for 45% of the total number of captured OPAs in this project. This makes the average OPA size 14.9 hectares, 27.8% of the provincial average—the smallest among the three regions.

TABLE 3 | Prime agricultural land loss in central Ontario.

County	Census farmland (ha) 2001	Prime agricultural land loss (ha) 2000–2017	Percentage loss (%)	OPA number	Average OPA size
York	71,211	7,989	11.22	17	469.9
Peel	42,263	3,442	8.15	6	573.7
Halton	39,966	2,938	7.12	11	267
Niagara	94,218	2,087	2.22	45	46.4
Durham	133,662	1,693	1.27	5	338.6
Simcoe	218,882	2,426	1.11	45	53.9
Waterloo	91,378	1,019	1.12	7	145.6
Peterborough	104,669	796	0.76	12	66.3
Wellington	190,764	935	0.47	28	33.4
Hamilton*	56,202	186	0.33	21	8.9
Haldimand	86,590	284	0.33	21	13.5
Dufferin	78,170	247	0.32	8	30.9
Kawartha Lakes	145,966	236	0.16	23	10.3
Northumberland	102,654	63	0.06	6	10.5
Brant	64,221	64	0.1	5	12.8
Total	1,520,816	24,404	1.6	260	93.9

*The City of Hamilton's results are not directly comparable to other regions in this Table as the dataset is not considered to be complete or verified.

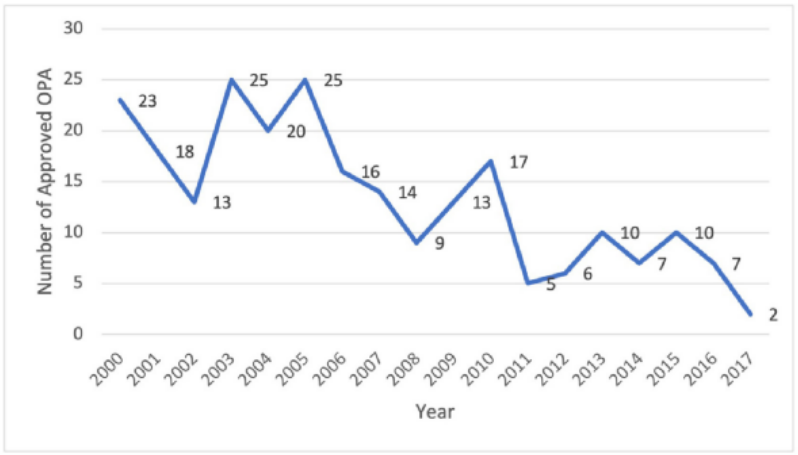

Chart 3 | Number of yearly approved OPAs in Central Ontario.

Most cases for farmland conversion in Southwestern Ontario were small-scale applications intended to create small lots on existing agricultural land, allowing for non-agricultural uses, such as commercial, recreational, residential, and agricultural-related facilities. The "rural" designation does not exist in most local municipalities' Official Plans within Southwestern Ontario. As a result, most of the farmland losses were captured under the categories of "redesignation for development use" or "non-farm use through site-specific policies" (**Table 6**).

In Southwestern Ontario, there was no obvious upward or downward trend regarding the annual loss of prime agricultural lands and approved numbers of OPAs (**Charts 4A,B**). The years 2008 and 2017 saw the most approved OPAs with 20 each and most farmland loss occurring in 2008. Relative to the rest of the province, particularly Central Ontario, the rates of urban development have been more limited within Southwestern Ontario. This finding is unsurprising given that Southwestern Ontario has the highest provincial share of productive farmland and a competitive and

TABLE 4 | Area of official plan amendments categorized by purpose and proportion of total OPAs (%).

Purpose of OPA for redesignated use	Proportion of total OPAs (%)
Comprehensive official plan update (MCR)	72
Employment	10
Recreational	4
Municipal infrastructure	4
Residential	4
Industrial	2
Mineral extraction	2
Commercial	1
Institutional	1

prosperous regional agricultural industry. Given these regional characteristics, these trends may illustrate the lesser development pressures contributing to farmland loss relative to the more rapidly urbanizing and populated Central Ontario.

Southeastern Ontario

The Southeastern region of Ontario has the lowest proportion of census farms and prime agricultural land (**Table 7**). Bedrock geology characterizes a large proportion of this area. Consequently, this area has the lowest capability of agricultural soils and, in turn, the lowest amount of prime agricultural land loss. Between 2000 and 2017, 1,272 hectares of prime agricultural land were redesignated to non-farm uses, representing ∼5% of the total captured prime agricultural land loss in this project. The average OPA size in this region is 32.6 hectares, 60.8% of the provincial average.

The Southeastern region had the lowest number of relevant OPAs among the three areas within the study period, with each county reporting <10 relevant OPAs (**Chart 5A**). Like Southwestern Ontario, there is no obvious upward or downward trend regarding annual prime agricultural land loss. The most OPAs approved, and the highest amount of primary agricultural land loss were in 2008 when 8 OPAs converted 394 hectares of prime agricultural lands (**Chart 5B**). Proportions of OPAs contributing to this total land loss include development redesignations (54.7%), rural redesignations (30.4%) and site-specific policies (14.9%) primarily (see **Table 7**).

DISCUSSION: THE STRENGTH OF PROVINCIAL FARMLAND PROTECTION POLICIES

In tracking agricultural land conversion through regional and local OPA decisions, this article indicates patterns of future farmland loss in Ontario and the effectiveness of agricultural land preservation policies in real-time. Our analysis presents that 545 OPAs were approved, converting 29,217 hectares of prime agricultural land in southern Ontario from 2000 to 2017. While rates and nature of farmland loss vary regionally across the study area, large-scale farmland conversion caused by urban boundary expansion dominated Central Ontario, the region with the most significant population growth. Also, it accounted for the highest amount of farmland loss. In terms of the area lost, Southwestern and Southeastern Ontario accounted for the following highest levels of farmland loss during this period, respectively, due to an accumulation of permissions for site-specific uses. The highest peaks of farmland loss were accounted for in 2006, 2013, and 2015 as part of local MCRs and large-scale urban boundary expansions, reiterating the threats urban sprawl imposes on farmland loss. However, while most farmland loss results from large-scale urban boundary expansions, the cumulative effects of farmland loss resulting from rural designations and site-specific policy amendments on individual parcels should not be underestimated. Results in this study evidence a general decline in farmland loss in 2010–2014 relative to the 2000–2004 and 2005–2009 periods, before the establishment of provincial farmland preservation policies in 2005.

Overall, this article (**Table 8**) demonstrates that the establishment of several provincial policy initiatives in 2005, including the revised Provincial Policy Statement, the Growth Plan, and the Greenbelt Plan, has successfully minimized the rates of farmland loss and protected prime agricultural lands. For example, the Growth Plan establishes density and intensity requirements that several urban centers and regions outside of the Greenbelt (not subjected to Greenbelt Plan policies) need to adopt and implement into their Official Plans. While not prohibiting development in prime agricultural areas directly, these growth management policies facilitate the densification and intensification of urban areas and the mitigation of urban sprawl—highlighting the "other side of the coin" to farmland protection in land-use planning. Overall, these policies establish a framework that consistently contributes to enhanced municipal control over agricultural land conversion in southern Ontario.

The Inner Ring municipalities have played increasingly active roles in agricultural land protection with both planning approaches and local initiatives. The Outer Ring municipalities have seen increasing urbanization pressure. Data on farmland loss showed a mixed landscape of large-scale municipality-led urban boundary expansions and small-scale individual applications on policy changes to allow for non-agricultural uses. Southwestern Ontario has experienced limited urbanization during the past two decades, and this research did not detect an obvious upward or downward trend of farmland loss in these areas. Most of the farmland conversion cases in this area were small-scale applications to create small lots on existing agricultural land to allow non-agricultural uses such as commercial, recreational, residential, and agricultural-related facilities. Southeastern Ontario has the smallest provincial share of prime agricultural land and has seen minimal farmland loss

TABLE 5 | Redesignations in the inner ring of the Greenbelt, 2000–2017.

County/region	Number of approved OPAs related to the loss of prime agricultural land	Prime agriculture redesignated to:		
		Development (ha)	Rural (ha)	Non-farm uses through site-specific policies (ha)
Durham	5	1,619	56	18
Halton	11	2,656	0	282
Niagara	45	1,001	240	847
Peel	6	3,316	0	127
York	17	5,233	2,756	0
Hamilton	20	34.5	0	152
Inner ring total	104	13,860	3,052	1,426
Brant	5	0	0	63.5
Simcoe	45	2,034.2	82	310
Waterloo	7	1,019	0	0
Wellington	29	817	32	88
Haldimand	21	71	0	213
Peterborough	12	746	15	34
Dufferin	8	59	0	188
Northumberland	6	2	60	2
Kawartha Lakes	23	129	50	57
Outer ring total	156	4,877.2	239	955.5

TABLE 6 | Redesignations in Southwestern Ontario, 2000–2017.

County/region	Number of approved OPAs related to the loss of prime agricultural land	Redesignations in Southwestern Ontario 2000–2017			
			Prime agriculture redesignated to:		
			Development (ha)	Rural (ha)	Non-farm uses through site-specific policies (ha)
Grey	15	136	0	107	29
Huron	2	25	25	0	0
Perth	72	756	254	0	502
Middlesex	15	175	78	0	97
Lambton	31	540	285	0	255
Chatham-Kent	16	132	74	0	58
Elgin	7	242	242	0	0
Bruce	35	136	43	0	93
Oxford	16	869	842	0	27
Norfolk	37	519	85	0	434
Essex	0	0	0	0	0
Total	246	3,541*	1,928	107	1,495

*Totals may not add due to rounding.

since 2000. Most of which were small-scale individual application on land-use redesignations (partially reflecting reduced acreages of prime farmland). The provincial policy impact on farmland preservation is not as obvious in this geography.

The connection between minimized rates farmland loss and provincial farmland protection policies is particularly evident within Ontario's Greater Golden Horseshoe, particularly within the Inner Ring, also the Greenbelt Plan Area. During the initial

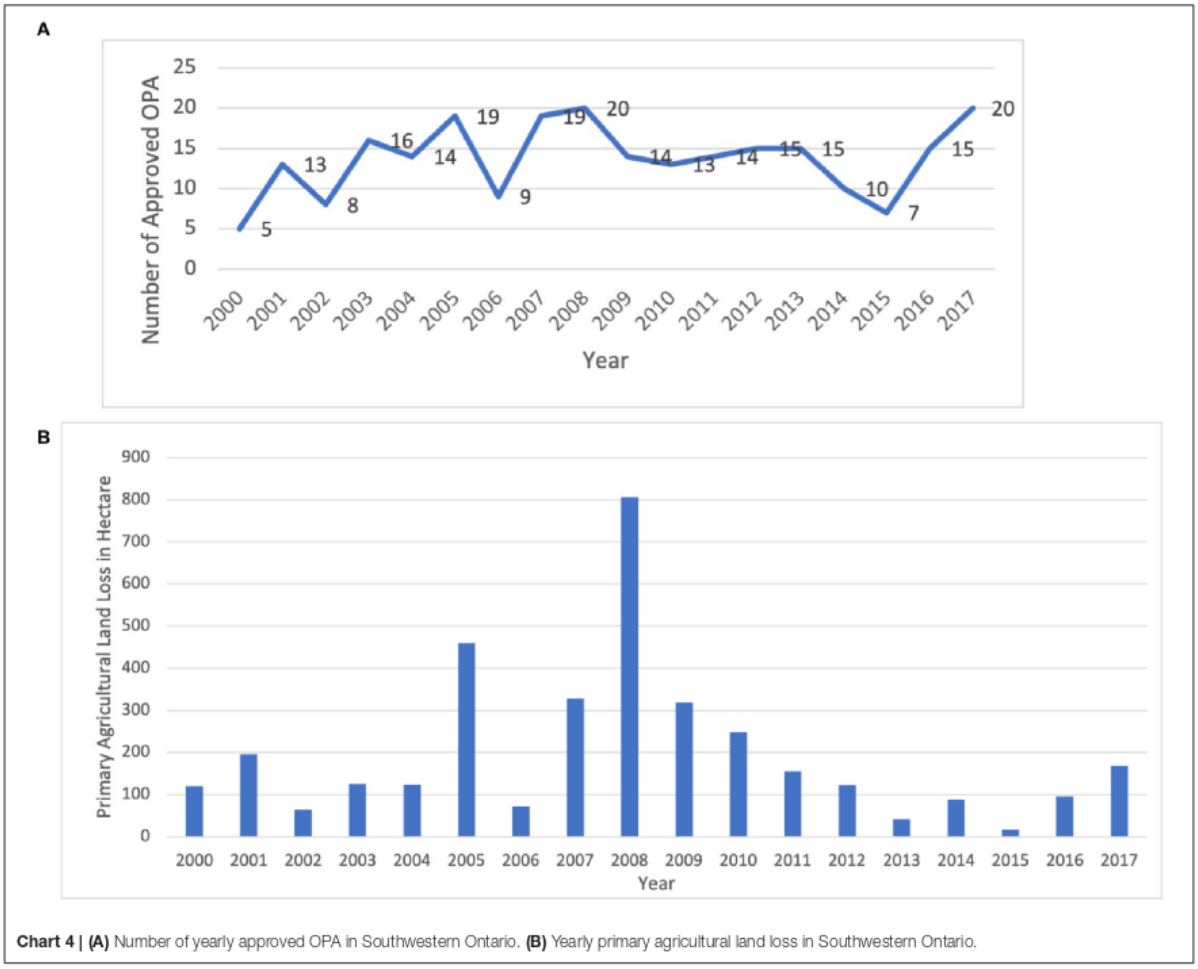

Chart 4 | (A) Number of yearly approved OPA in Southwestern Ontario. **(B)** Yearly primary agricultural land loss in Southwestern Ontario.

implementation of the Greenbelt Plan in 2005, there was much scrutiny (and doubt) within Ontario from several stakeholders over the perceived efficacy of the policy (Hume, 2010). For example, anecdotal accounts share how farms in the Greenbelt's "protected countryside" were subject to development after the initial onset of the Greenbelt in 2005—signaling a perceivable policy failure amongst Ontario communities (Epp and Caldwell, 2018). However, as noted in our article, quantifiable evidence illustrates this is not the case. These agricultural parcels were "lost" to development at the time of the planning decision, which would have occurred before the implementation of Greenbelt policies. For instance, before establishing the Greenbelt Plan, there were 1,427 hectares of prime agricultural land redesignated across the Greater Golden Horseshoe between 2000 and 2004 within the current Greenbelt boundary. Approximately 1,420 hectares of the converted farmland were located in the Inner Ring area, and only 7 hectares of farmland were converted in the Outer Ring area. The annual average farmland loss in the Inner Ring area was 284 hectares. Since the Province of Ontario enacted the Greenbelt Plan, the total farmland loss in the Inner Ring area within the Greenbelt boundary dropped to 13 hectares during 2005–2017, making the annual average loss only 1 hectare. There were only three OPAs approved since the establishment of the Greenbelt, which affected prime agricultural land within the Greenbelt boundary. This article shines a light on the success of the Greenbelt Plan, evidencing the effect of the Greenbelt policies on farmland protection when comparing communities with high development pressure to those outside of the protected countryside. Moreover, these findings reiterate the lessons from other Greenbelt policy areas in the world to illustrate the critical and pivotal role policy plays in mobilizing sustainability and farmland protection within policy-protected areas (Carter-Whitney, 2008).

Concerning the success of other farmland protection policies, our analysis suggests that for those areas outside of the Greenbelt and Growth Plan areas, the agriculture policies of the Provincial Policy Statement have performed reasonably well in protecting prime agricultural lands. For example,

TABLE 7 | Redesignations in Southeastern Ontario, 2000–2017.

County/region	Number of approved OPAs related to the loss of prime agricultural land	Prime agriculture redesignated to:		
		Development (ha)	Rural (ha)	Non-farm uses through site-specific policies (ha)
Ottawa	3	132	41	6
Prescott and Russell	5	51	137	29
Stormont, Dundas, and Glengarry	9	1.4	120	33
Leeds and Grenville	3	186	12	7
Renfrew	3	0	54	0
Hastings	7	40	179	0
Prince Edward	9	0	110	137
Frontenac	0	0	0	0
Lennox and Addington	0	0	0	0
Lanark	0	0	0	0
Total	**39**	**777**	**431**	**212**

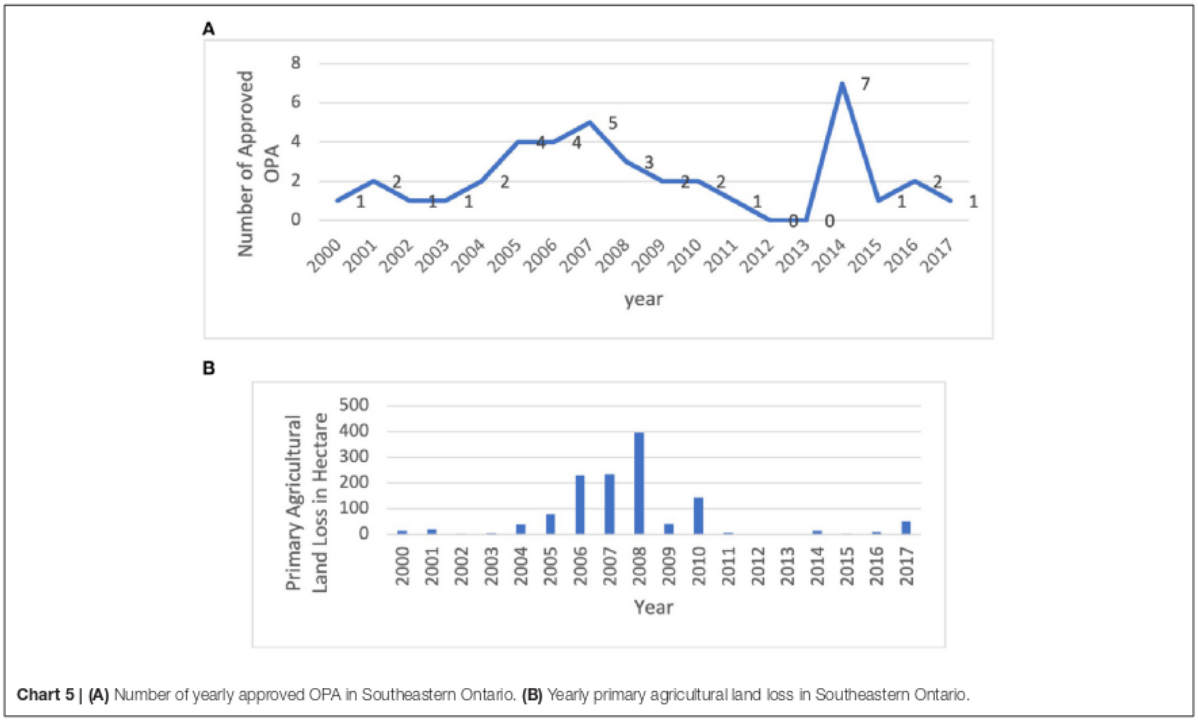

Chart 5 | (A) Number of yearly approved OPA in Southeastern Ontario. **(B)** Yearly primary agricultural land loss in Southeastern Ontario.

outside of the Greenbelt, there has been an overall declining rate of farmland loss across the Greater Golden Horseshoe since 2005. Annual farmland loss outside the Greenbelt has dropped by almost 50%. Both the Inner Ring area and the Outer Ring have seen a decline in yearly farmland loss. The average of the Inner Ring's annual farmland loss dropped by 40%, whereas the average of the Outer Ring's annual farmland loss dropped by 75%. This is evident in regions such as southwestern and Southeastern Ontario, where only one policy layer (the PPS) is applied and implemented to protect prime agricultural lands at the municipal level, and trends of farmland loss are relatively low or consistent throughout 2000–2017. This is relative to areas subject to multiple layers of farmland protection policy, however, such as Central Ontario,

TABLE 8 | Prime agricultural land conversion in GGH 2005–2017.

Region	Within the Greenbelt		Outside the Greenbelt	
	2000–2004	2005–2017	2000–2004	2005–2017
GGH PAL loss	1,427	31	10,061	12,433
GGH Annual PAL loss	285	2.4	2,012	956
Inner Ring PAL loss	1,420	13	6,540	10,178
Inner Ring Annual PAL loss	284	1	1,308	783
Outer ring area Total PAL loss	7	18	3,521	2,255
Outer Ring Annual PAL loss	1.4	2.4	704	173

which is experiencing consistent development pressure (i.e., the highest amount of farmland loss, urbanization, and population growth) and why we bring focus to this policy area in our discussion. Overall, the provincial-wide analysis of farmland loss has provided a way to evaluate whether more robust policy instruments are needed elsewhere in the province beyond the Greenbelt area.

CONCLUSIONS

This article reviewed southern Ontario's farmland preservation and urban expansion policies and evaluated their effectiveness with quantitative data. By tracking the agricultural land conversion through local Official Plan Amendments, this study documented farmland loss across Ontario between 2000 and 2017. Provincial policies and local municipalities' role in preserving farmland in different geographic regions were analyzed.

At a provincial level, data from 36 counties/regions shows that the provincial policies and local planning framework have perceivably worked in tandem to affect the agricultural land base in southern Ontario significantly. At a regional level, however, this study reveals that the loss of prime agricultural lands and resulting policy implications are focused within Central, rather than Southwestern or Southeastern, Ontario. In Central Ontario, which is the most urbanized area in Ontario, the Province's Greenbelt Plan has significantly reduced the rates of farmland loss within this geographic range since 2005. Elsewhere within the province, the Provincial Policy Statement and the Growth Plan, for example, establish requirements that municipalities are expected to adopt and implement into local Official Plans, which protect farmland in different ways.

This research has introduced a planning-based methodology to track the availability of agricultural land and has documented the farmland conversion at regional and municipal levels. Measuring approvals at this level can help describe prominent regional trends, successes, and failures in helping to guide growth as it occurs in real-time. This methodology has potential broader applicability in Canada and elsewhere, where land-use decisions primarily involve municipal governments. Moreover, the data in this research has provided a baseline for future farmland availability research, and has created a framework for further policy, agricultural, economic, and planning research.

DATA AVAILABILITY STATEMENT

The datasets presented in this study can be found in online repositories. The names of the repository/repositories and accession number(s) can be found at: http://www.waynecaldwell.ca/projects/.

AUTHOR CONTRIBUTIONS

All authors listed have made a substantial, direct, and intellectual contribution to the work and approved it for publication.

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Conflict of Interest: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Factsheet 6
Fruit and Nut Varieties at The Food Forest

At The 'Food Forest' we are trialling a large number of cultivars of other fruit and nut species. The project started in 1983 and the aim was to find varieties that are well adapted to our total environment: soils, water, climate, pests and diseases and low input orchard management. We are also aiming to satisfy the requirement for a steady flow of produce all year.
Our selections are particularly applicable to growing in warmer climates on neutral to alkaline soils.

Climate change is altering our climate rapidly and many old varieties will no longer pollinate reliably because of a lack of winter chill (see the paper on our website under 'academic papers'). Conversely the extreme heat experienced over more recent summers has severely damaged some varieties; they will also be removed from the list.

Please Note: No liability is accepted for catastrophes occurring subsequent to your use of this information sheet. It is simply a collection of our observations at The Food Forest. The best performers are asterisked * Those not yet bearing have a ?

APRICOTS

Variety	Ripening Date	Description
Story's Early	Mid Nov	Moorpark type, Good for jam or bottling
Solar	End Nov	Good size and flavour
Fireball	End Nov	Good crack resistance, flavoursome
Tilton	Late Dec	Medium size, excellent flavour. Careful picking req, stalks pull out easily
Trevatt	Late Dec	Large fruit, commercial canning variety
Moorpark *	End Dec	Principal commercial variety, excellent for drying and jam
Hunter	Jan	Drying
Mystery	Jan	Large fruit which hangs well, good flavour , bottle, dry, fresh or jam

Note: minimal pruning and good hygiene are needed to prevent Gummosis in Apricots. Many people prune in summer to promote rapid healing of cuts

NECTARINES

Variety	Ripening Date	Description
Firebrite	Late Dec	Yellow Fleshed, very high quality *but needs strong spray regime*
*Flavortop	Mid Jan	Regular yielder, yellow fleshed
*Goldmine	Late Jan	White fleshed, old standard

New boy	Early Feb	Medium size, white flesh, crimson skin
*Peacharine		Highly coloured, yellow flesh, good size
No bubble no trouble	Mid Feb	Maroon over green white flesh
Sundowner 6-3N	December	Low chill variety
Arctic Rose		Red over cream, super sweet PBR
Forest Silver	Mid-late Jan	Larger fruit than goldmine…otherwise similar

PEACHES

Variety	Ripening Date	Description
Sherman's Red	Late Nov	Yellow flesh, needs significant thinning or fruit are very small
Anzac	Late Dec	White flesh, freestone, reliable, fragile (in terms of handling fruit)
*Flavorcrest	Late dec	Yellow fleshed, freestone, large fruit
Elberta	Late Jan	Yellow fleshed, freestone, most useful dessert and bottling variety
JH Hale (Million Dollar)	Late Jan	Yellow fleshed, freestone, large, highly coloured, dessert and bottling variety
*Flamecrest	Early Feb	Yellow flesh freestone
Millicent	Mid Feb	White fleshed, freestone, best last white fleshed peach, heavy cropper
Red Noonan	End Feb.	High Yielder, small fruit, deep red, white flesh
*Late Italian Red	April	Yellow fleshed firm . Brightly coloured fruit
Tasty Zee	End Feb?	White flesh, sweet, freestone
Emily Kirsten	Late Jan?	White flesh, sweet
Fragar	Jan?	Semi clingstone, white flesh
O'Henry	End feb?	Large, firm, yellow freestone with full red skin, big commercial cv
*Kirkman	Late Mar	Yellow Freestone
Angel	Late Dec-Jan	Flat shaped, white flesh, sweet, **easily damaged**

Note: Protection from fungi (using copper and sulphur sprays) is required for good consistent production of nectarines and peaches in our management system.

PLUMS

European plums honey coloured flesh

Variety	Ripening Date	Description
Angelina	Feb	Purple skin, excellent firm flesh
Stirling	Mid feb	Large, heart shape, yellow, pink flesh, deep red over yellow

Blood plums (red flesh)

Satsuma	Late Jan	Good flavour, pollinates Mariposa

*Mariposa	Early Feb	Good flavour, pollinates Satsuma
Donsworth	Feb	Dark red, light red flesh, sweet, clingstone
Ruby Blood	Mar	Dark red skin, sweet burgundy flesh

Japanese Plums

Variety	Ripening date	Description
Wilsons Early	Early December	Fair flavour
Santa Rosa	Late December	Excellent flavour

PRUNE Plums (amber flesh, very sweet, can be transformed into prunes, tough trees)

Variety	Ripening date	Description
*D'Agen	March	Purple skin
Robe d'Sarge	April	Small intensely flavoured fruit
Splendour	Early	Medium fruit, red-purple skin

PLUOT (plum-apricot cross)

Flavour supreme	Feb	Sweet apricot aroma

PLUM X NECTARINE (interspecific hybrid)

Spicezee (self fertile)	March	Maroon skin. Firm white flesh, sweet

CHERRIES. Cherries have generally not done well on the Adelaide Plains. Birds are extremely fond of cherries.

Variety	Ripening Date	Description
Stella	Christmas	Self fertile

APPLES All of these varieties are dessert apples and do well at Gawler

Variety	Ripening date	Description
Jersey Mac	Late December - Jan	Mainly red, white flesh, good quality
*Akane	February	Red with green and gold stripes, acid
Johnafree	Early March	Jonathon type apple with resistance to Apple Scab
Dayton	March	Red Apple…very productive, sunburn susceptible
Red Delicious	March	Red skin, berry like flavour
*Gala	March	Red striped, juicy and sweet
Golden Delicious	April	Sweet, juicy, green to golden skin
**Granny Smith	May	Acid and crisp, green skin
*Fuji	Late April - May	Red/green apple, crisp
*Pink Lady	May	Crisp, acid/sweet, pink skin

Abas		
Sundowner	June	Acid, crisp, red skin
**Lady William	Mid June - July	Acid, crisp, red skin
Northern Spy		Wooly aphid resistant and used as an important rootstock. Also drought hardy and excellent for apple pie and cider

Note: Apples produce a bigger crop when cross pollinated. Red Delicious must have a pollinator

PEARS

Variety	Ripening date	Description
*Duchess (also known as Williams)	Late Jan	Most popular variety, juicy white flesh
*Sensation	Feb	A red version of Duchess
*Beurre Bosc	April	Classic French variety, firm and slightly scented
*Packham Triumph	April	Good keeper, needs cross pollination, low chill req
Commice du Doyen	April	Superb texture and flavour
Corella	April	Pink coloured , smallish fruit of excellent texture
Lemon Bergamot	Late March	Medium size, round, yellow-green with red blush
*Vicar	April	Large, great for salads

NASHI PEARS

Variety	Ripening date	Description
*Kosui	Feb	Golden skin, crisp, juicy white flesh
Hosui	Feb	Bronze skin, white juicy flesh
Neijisseiki	Late Feb	Green skin, crisp, acid, white flesh
*Ya Li	Late Feb	Chinese variety, pear shaped and good acid balance
*Tsu Li	Late feb	Chinese variety, pear shaped and good acid balance

QUINCES

Variety	Ripening date	Description
Pineapple*	March	Distinctive flavour, medium size
Smyrna*	Late March, April	Excellent quality, stores to Sept

ORANGES

Variety	Ripening date	Description
*Washington Navel	May-September	Seedless
*Leng Navel	July-August	

*Valencia Improved	October-April	Only the improved strains will hang well, excellent juicing quality
*Seville	July	A bitter orange regarded as the best variety for marmalade making. Strong grower
?Salustiana orange	Aug	Sweet, few seeds, good flavour
Lane's Late Navel	Sept	Large, excellent late colouring and holding on tree

GRAPEFRUIT

Variety	Ripening date	Description
*Marsh	June-August	Seedless, holds on till Nov
*Ruby	August	Slightly pink fleshed
Thompsons	September	Pink fleshed
?Oroblanco	May- Nov	Yellow flesh

LEMONS

Variety	Ripening date	Description
Lisbon*	All year (less in summer)	Prolific bearer
Eureka*	Main crop August but partial summer bearer	
Villa Franca	Main crop July but partial summer bearer	
Meyer*	Early June	Slightly less acid (orange cross)

THAI LIME

Variety	Ripening date	Description
Karamondin	Leaves harvested all year, fruit May-August	Flavours Asian food, marmalade

MANDARINS

Variety	Ripening date	Description
Early Imperial*	June	
Japanese Seedless*	Late June	Large , sweet, thin skin
Dancy	Early July	Bright colour
Ellendale*	August	
Kara*	September	Excellent flavour
Daisy	June-Late July	Top flavour with few seeds, (trifoliata stock)

TANGELO

Variety	Ripening date	Description
Minneola*	August	An easy peeling variety, cross between mandarin and grapefruit

KUMQUAT

Variety	Ripening date	Description
Kumquat	June - September	Ideal for brandying or marmalade
Nagami*	Multiple crops	Sweet skin – can be eaten from the tree
Meiwa	August	Large, round, acid variety

LIME

Variety	Ripening date	Description
*Tahitian	July -November	Heavy bearer, acid, highly flavoured, seedless
Australian Lime	June - Oct	A selection of Tahitian?

LIMEQUAT

Variety	Ripening date	Description
Limequat	Sept	Said to be prolific bearer. Cold-hardier than Tahitian lime

CAROB

Variety	Ripening date	Description
Sfax*	March-April	Popular eating variety, hard flesh
Tyiliria	March-April	Sweet
Casuda*	March-April	Sweet, productive tree
Gabriel or Clifford*	March-April	Hermaphrodites - for pollination - prolific but low quality pods

OLIVES

Variety	Ripening date	Description
Manzanillo	May	Dual purpose, highly productive for pickling
Verdale*	May	Dual purpose, highly productive
Barouni*	May	Mainly for pickling, high quality
Kalamata*	May	High quality pickling olive, 2nd pick good for oil
Del Marocco	May	Heritage variety, excellent oil

Mission	May	Popular US variety, dual purpose
Corregiolla*	May	Premium oil variety
Frantoio*	May	Premium oil variety

JELLY PALM

Variety	Ripening date	Description
Seedlings	March	Fresh eating but fibrous, also good for jelly, wine

MACADAMIA

Variety	Ripening date	Description
A38	August	Prolific bearer, high quality

Can be grown but are outside their commercial climate range in Southern Australia

CHESTNUT AND HAZELNUTS Have not flourished under our conditions

ALMONDS

Variety	Ripening date	Description
California Paper Shell*	February	Good quality but very susceptible to bird damage
Chellaston	February	Soft shell, good large kernel
Fritz*	February	Pollinator for Non Pareil
Johnstons Prolific	February	Pollinator for Chellaston
Dwarf papershell	February	Self pollinating Very susceptible to bird damage

WALNUTS

Variety	Ripening date	Description
Serr*	May	Vigorous tree, large nut
Tehama	May	Pollinates Serr, weak seal on shell, sunburns
Vina*	May	Vigorous, medium sized nut, very productive
Hartley	May	Pollinates Vina, high quality medium sized, lacks vigour
Franquette	May	Pollinates Hartley, large nut, sunburns

PISTACHIO

Variety	Ripening date	Description
Sirora* (female)	March	Most productive cultivar
14-4, or 15-13 (males) Necessary for pollination		

Sfax (female) low chill adapted	March	High rate of splits, small nut, upright grower

PECAN: Note: Pecans need plenty of good water. Extra zinc is almost always needed

Variety	Ripening date	Description
Western Schley*	July/August	Large nut, self fertile
Cherokee*	July/August	Small tree, probably self fertile
Desirable	July/August	Large nut, consistent bearer
Tejas	July/August	Large nut, pollinated by Western Schley

FIGS. Note: Figs also produce a small high quality early (Breba) crop before Christmas

Variety	Ripening date	Description
White Genoa (the sugar fig)	Early January	Light brown skin when ripe, good for drying or jam
Archipal	February	Thin skinned, can be eaten without peeling, green/gold skin with cream coloured flesh
Deanna	Early March	Golden skin, champagne flesh
Black Genoa*	March	Reliable, dark skin, red flesh
Spanish Dessert	March	Spectacular black fig with deep red flesh, needs cross pollination by Capri fig for reasonable crops

FEIJOA

Variety	Ripening date	Description
Mammoth*	Feb	Big! (The varieties below pollinate each other)
Triumph	May	
Bartsch*	May	Large fruit, heavy bearer

WHITE SAPOTE: Note: White Sapote's requite cross pollination

Variety	Ripening date	Description
Ortega*	April-May	Excellent fruit
Vernon	May-June	Good pollinator
Julienne	April	Prolific bearer
Pike*	May	Excellent quality, prolific

LOQUAT

Variety	Ripening date	Description
Enormity*	October	Large fruit of reasonable quality
Chatsworth Victory	October	Excellent flavour
Mammoth	October	Large fruit, deep yellow flesh

TABLE GRAPES

Variety	Ripening date	Description
Perlette*	February	White seedless, small berries (kids love them)
Thompson's Seedless*	February	White, seedless
Muscat Hamburgh	Early March	Black, muscat flavoured
Malaga	Early March	White, good for drying to raisins
Italia*	March	Yellow, aromatic, large berries
Ruby Seedless	March	Red seedless berries, of good size
Karina*	March	A currant type
Crimson seedless	Mid-late season	Bright red, seedless, cane pruned
Red globe*	Late	Very large, seeded, spur pruned PBR
Ruby seedless	Late	Heavy crop, small, dark red, sweet and crisp

PERSIMMON

Variety	Ripening date	Description
Dai-dai Maru*	June	Luscious, sweet, astringent type. Must be allowed to mature properly to attain a sweetness
Fuyu*	June	Non astringent type

BANANA

Variety	Ripening date	Description
Lady Finger	November	A sweet firm little banana
Silk Banana*	November	Bunches need protection to escape fungus damage

MULBERRY

Variety	Ripening date	Description
Hicks Fancy	Late October -November	Lacks intense flavour but is excellent for jams
Chinese White	November	Good for jams etc
Persian White*	December	Caramel flavour, excellent dried
Old English Black*	Late December	Intense flavour
Shahtoot	November- December	Heavy cropper, sweet white, long fruit (commercial)
Dwarf Shahtoot	Nov-Dec	Dwarf tree with reddish fruit as above

CHERRY GUAVA

Variety	Ripening date	Description
Red	July	Acid, refreshing

Yellow*	July	Sweeter than the red variety and reliably nice eating

CHINESE DATE (JUJUBE)

Variety	Ripening date	Description
*Li	April	Large good quality
*Small	April	Very small fruit of very high quality
Lang	April	Medium fruit, pear shape

Refer to Ben Waddelow, SA Rare Fruit Soc for up to date info on jujubes. He is a goldmine of info and a propagator.
Enter contact details

POMEGRANATE

Variety	Ripening date	Description
* Wonderful	April-May	Large, good quality, dark red seeds, sweet
Giant	April	Very large, good quality, pale pink seeds
Veles	April-May	Medium sized, dark red seeds

KIWI FRUIT

Variety	Ripening date	Description
Abbott (female)	June	Long shape, relatively hardy
Matua (male)	June	

BERRIES

Variety	Ripening date	Description
Boysenberry	November- December	Thorny but delicious and hardy
Youngberry	November- December	A thornless cultivar exists

Curry Leaf (Murraya koenigii), Common Guava, Stone Pine, Tamarillo, Passionfruit, Avocado, Quandong also grown. Plum-Pine and other Bush Tucker species are also under trial.

Web addresses:

- **Gol Gol Nursery (Mildura) has an excellent range and freights trees to SA. See** www.golgolnurseries.com.au
- Fleming's nursery in Vic www.flemings.com.au. See also Graham's factree at http://www.factree.com.au . You can subscribe to their e-newsletter for free.
- Chris and Diana Perry's nursery site is at: http://www.perrysfruitnursery.com.au/index.htm
- The SA Rare fruit society has a members site with lots of info and has a list of budwood available from its foundation plantings at eg http://www.rarefruit-sa.org.au/Varieties.htm#Sapote

Balhanna Nursery, Charleston, SA Temperate trees especially pome and stone fruit
Website: www.**balhannahnurseries**.com.au

Limestone Nursery, Broken Hill – Specialists in Carob trees. http://www.carobtrees.com/

Excellent book: ‘The complete book of Fruit Growing in Australia’, Louis Glowinski.

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Benefits of the ecosystem services provided by urban green infrastructures: Differences between perception and measurements

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ABSTRACT

Urban green infrastructures (UGIs) are being increasingly recognized as key providers of ecosystem services (ES) in cities. However, many developing countries still lack the public awareness of the concepts of UGIs and their ES, including the benefit & monetary value of the UGIs' services, the willingness to pay (WTP) for the UGIs' services. The relationship between the benefits & monetary value of and the WTP for the services of UGIs has not been extensively investigated. These two aspects were respectively defined as ES supply and as ES demand in the current study, in which their relationship was scientifically described. Meanwhile, the influential factors of the deviation between ES supply and ES demand were explored. Adopting Guangzhou City (China) as a case, the main ES supply of UGIs in three public green spaces including air pollutant removal, daytime temperature reduction, rainwater runoff regulation, and noise abatement was first assessed with field measurements. Further, the main ES demand including people's preferences, satisfaction, and WTP for the UGIs' ES was analyzed with survey and statistical analysis. In total, 405 valid questionnaires were distributed to collect the data of ES demand and were analyzed by the nonparametric Kruskal-Wallis H test and a binary logistic regression model. The monetary valuation was used to unify the benefit valuation standards provided by different ESs, so as to more intuitively reflect the contribution of different ESs and compare these with ESs demand which uses WTP as one of the indicators. The results showed significant differences between ES supply and ES demand. The major evidence was that the regulation services could supply most of the ES benefits, while the cultural services were the most demanded by respondents. People had diverse sensitivity to the different types of ES provided by the UGIs. Cultural services were the most easily perceived by the respondents and considered as the top one, followed by regulation services. In addition, the outcome of the survey revealed different criteria regarding ES demand by people, and varying influencing factors for people's satisfaction and WTP. Benefits, such as education opportunities, entertainment, and health values provided by UGIs in cultural services were more favored by respondents. Last, the statistical analysis confirmed that sociodemographic factors significantly influence people's WTP. This study suggests that UGIs should be oriented towards multifunctional construction, thereby emphasizing the relationship and balance between ecological integrity and social perception.

1. Introduction

Cities play an important role in promoting social and economic development (Yuan et al., 2006). With the continuous modernization in China, the population of cities has increased rapidly, leading to serious environmental problems. These issues are specifically occurring in Guangzhou, which is the center of economic activities and the national culture in southern China. The Population Reference Bureau (2016) noted that the growing urbanization and industrialization of developing countries caused serious health problems for urban residents. The physical environment within an urban context is an essential element that needs improvement.

Urban green infrastructure (UGI) is often used to alleviate environmental problems and to maintain the ecological environment (Bolund and Hunhammar, 1999). Referring to an interconnected green space network, UGI consists of various open spaces and natural areas, including greenways, wetlands, rain gardens, forests, and native vegetation (Foster et al., 2011). These areas provide a variety of benefits

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1618-8667/

that improve the quality of life in cities and are generally recognized as ecosystem services (ESs) (Costanza et al., 1997; Gómez-Baggethun and Barton, 2013). The 2005 Millennium Ecosystem Assessment grouped ES into four categories: provisioning services, regulation services, and cultural services and supporting services (Millennium Ecosystem Assessment (MEA), 2005; TEEB Foundations, 2010; TEEB Synthesis, 2010). The benefits and contributions of UGI to the ecological environment can be called the ES supply in this study. The awareness, satisfaction, and willingness to pay (WTP) of residents to different ESs provided by UGI can reflect the ES demand. People's perception and demand for the ecosystem benefits often have a certain degree of deviation from the objective value of ESs (Plieninger et al., 2013). This deviation is because that people's perceptions are often filtered through sensory inputs and then processed with regard to the relevant concepts and expectations about the input (Goldstone and Barsalou, 1998). People's cultural education background, moral beliefs, and life experiences influence the cognition and preference of ESs. Besides, the different geographical characteristics and architectural styles of UGIs are also influential factors. Hence, people's sense and awareness and demand of the ecosystem may not be consonant with the ESs supplied by UGIs (Costanza, 2000; Daily, 1997).

Several investigations on the ecosystem benefits that of UGIs in Guangzhou have been performed, mainly focusing focus on people's perceptions of the ESs and existing environmental risks. For example, Jim and Shan (2013) considered the influence of socioeconomic factors in Guangzhou on people's perceptions of the benefits of urban green space on human welfare. Duan et al. (2018) paid attention to people's perception of urban environmental risks and the effects of UGI on human well-being in Guangzhou. However, field measurement data for the ESs were relatively lacked and people's preferences for different types of UGIs were taken into account in the previous studies. Few relevant studies have focused on the relationship between the ES supply and ES demand, and the reasons for and influential factors of the deviation have not been explored widely.

This study investigates the differences between ES supply and ES demand provided by UGIs in three different public green spaces in Guangzhou. The real-time measurements were conducted to quantify the benefits of ES that UGIs can supply. Afterward, monetary valuation methods were used to convert these benefits into monetary value. To understand public demand for ESs, a questionnaire was designed to investigate people's awareness, satisfaction, and WTP. By comparing the ES supply and demand, this study explores the deviation between people's perception and the actual benefits of ESs provided by UGIs, and analyses the influential factors of the deviation. The outcome of this research can provide insight into humanized urban planning, which balances ecological integrity and social perception for urban planners.

2. Material and methods

2.1. Study area

This study focuses on the analysis of ESs in three public green spaces in Guangzhou, China. Guangzhou, located in the Pearl River Delta Metropolitan Region, is a megacity with more than 14 million residents (Guangzhou Statistics Bureau, 2018). Three public green spaces are respectively Flower City Square (FCS), Haizhu Lake Park (HLP), and Yuexiu Park (YXP) which all contain various vegetation types and are popular and easy to access. According to the topography and regional distribution of these parks, the areas close to the center of the parks were selected as the research points for either field measurement and survey. FCS (Fig. 1a) is the largest city square in Guangzhou. located at the new central axis of Guangzhou. Meanwhile, it is the commercial center and transportation hub in the most developed district (Ruilan, 2006). Water body is the main characteristic of HLP (Fig. 1b), which is located in the Haizhu district. The water area is broadly composed of two lakes, i.e., the inner lake and the outer lake. The outer lake is an annular water grid structure that composes six rivers. YXP (Fig. 1c) was one of the first established parks in Guangzhou. It is a mountain park with historical and cultural heritage. The park has a wide variety of plants and is a key tourist attraction nationally.

2.2. Conceptual framework

In order to compare and explore the relationship between the ES supply and ES demand, different methods and tools were applied to quantify and unify the values. Firstly, the real-time measurements were conducted to quantify the benefits of ESs that UGI can actually supply. Secondly, monetary valuation methods were used to convert these benefits into monetary value. Finally, a questionnaire was designed to understand public ES demand by determining people's awareness, satisfaction, and WTP. By comparing the ES supply and ES demand, the deviation between people's perception and the actual benefits of UGI's ESs was analyzed. Fig. 2 illustrates the conceptual framework of this research.

2.3. Ecosystem services supply (ES supply)

The measured parameters of the ESs were chosen based on the major environmental problems that have plagued Guangzhou citizens for a long time. The field measurements in this study focused on the ability of UGI to remove air pollutants, reduce daytime air temperatures, and mitigate rainwater runoff and noise abatement.

2.3.1. Air pollutant removal

2.3.1.1. Quantification method. PM_{10} and $PM_{2.5}$ have scattering and absorption effects on light, lowering the visibility and damaging the human cardiovascular system (Freedman, 1995). UGI is able to extract aerosols and chemicals from the atmosphere, depending on the type of vegetation used, planting density, etc., and trees can act as barriers to filter and absorb dust (Kocić et al., 2014). The capacity of this ES varies with plant species, the canopy area, the height of the canopy, the type and characteristics of air pollutants, and the local meteorological environment (Nowak, 1994; 2006).

By conducting real-time measurements of the air quality in the three parks and comparing the control plot which represents the average concentrations in the whole city of $PM_{2.5}$ and PM_{10} from the Guangzhou Meteorological Service (Guangzhou Meteorological Service, 2018), the reduction rates of $PM_{2.5}$ and PM_{10} by the three UGIs can be obtained and used as an indicator of the air quality improvement capacity observed in this study. The formula for calculating the PM reduction rate in green spaces is as follow (Hong et al., 2017):

$$PM(f)_i = \frac{C_0 - C_i}{C_0} \times 100\% \quad (1)$$

Where f is the $PM_{2.5/10}$ reduction rate in the park i, C_0 is the $PM_{2.5/10}$ concentration in the control plot (Guangzhou Meteorological Station), and C_i is the $PM_{2.5/10}$ concentration in the park.

2.3.1.2. Sites and data collection. The air quality was measured on August 25, September 26 and October 27 (2018) during the summer period in Guangzhou. The measurement sites were located at different functional areas of the three parks, including a shaded area, a lawn area, and a waterside area. Each measurement was carried out simultaneously at 1.5 m above the ground in the three parks. The daily monitoring period was from 9:00 to 17:00. The measured data were processed and collected every half hour. To determine the influences of the UGI on the air quality in the parks, the real-time data were compared with the data from the control plot (Guangzhou meteorological stations: 113°31′7.92″E, 23° 0′08.27″N) that represent the average value of the city. Handheld dust monitors (JCF-200 (CW-HAT200)) were used to monitor the mass concentrations of PM_{10} and $PM_{2.5}$ (supplementary document Table S1). The monitors were created

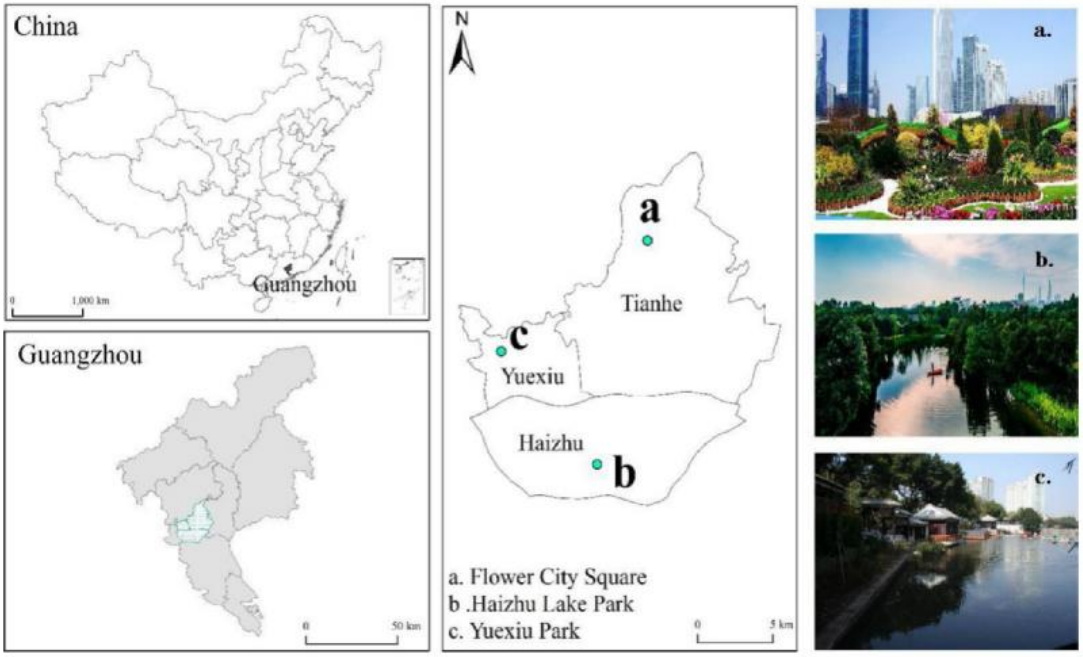

Fig. 1. Photographs and the geographical locations of the selected green spaces (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article).

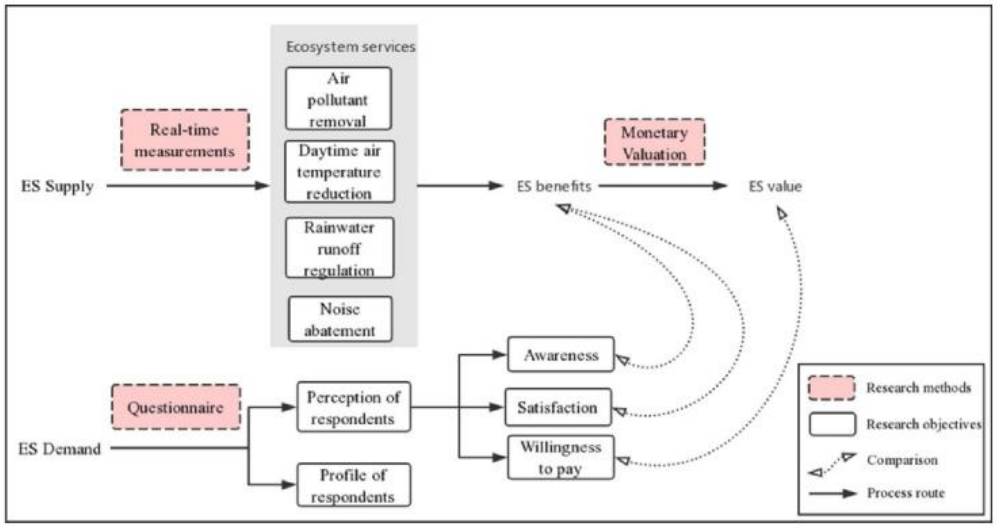

Fig. 2. Conceptual framework of research.

with a laser diode technique based on the advanced miniature laser sensor technique with high sensitivity, which can test the concentration of dust fine particulate matter in the air. Every instrument was cleaned and set to zero before measurement, and data logging would start when the measuring was functioning properly for 5 min.

2.3.2. Daytime air temperature reduction

2.3.2.1. Quantification method. Temperature reduction is one of the main ES supply of USI. UGI can lower the air temperature and wind speed through shading and wind sheltering. In addition, UGI can reduce temperature and increase humidity through photosynthesis, transpiration, and evapotranspiration of vegetation, which are effective ways to alleviate urban heating (Feyisa et al., 2014).

The increase in temperature not only affects ecosystem function, the physiology of plants and animals, and the physical and mental health of residents but also increases energy consumption, etc. The reduced temperature could be converted to the heat of the air absorbed by the plant's evapotranspiration in the UGI and then converted to the electrical energy required to reduce the corresponding temperature. A theoretical space with an area of 10 m^2 and a height of 100 m is then used as the calculation unit. Using Eqs. 2 and 3, the heat TQ consumed by the plant was derived (Zhang et al., 2014):

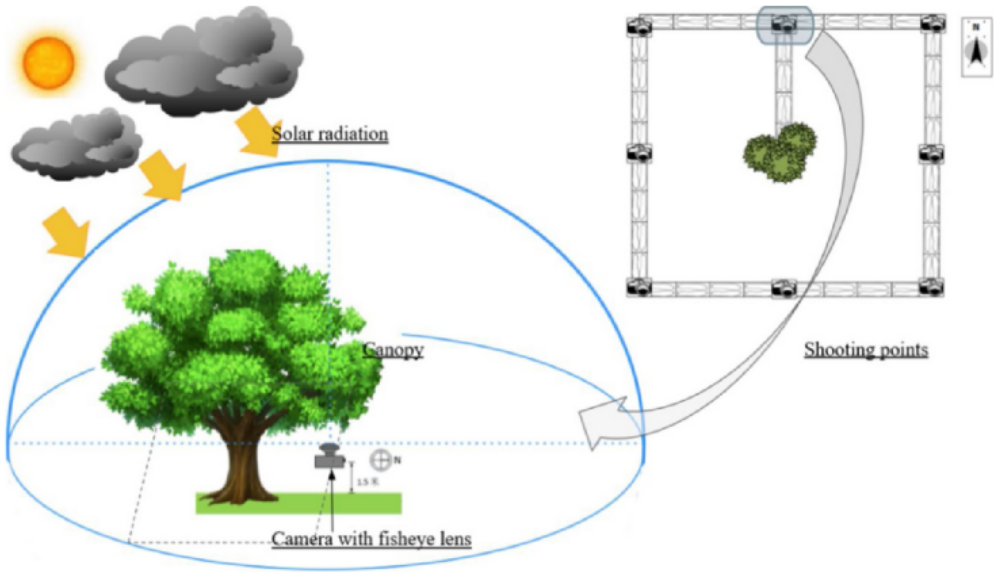

Fig. 3. Measurement scheme of LAI using fisheye photographs in the sample sites in each park.

$$\Delta Q = \Delta T \cdot P_C \quad (2)$$

$$TQ = \sum_{i=1}^{n} \Delta Q \cdot A_i \quad (3)$$

ΔQ: the heat absorbed by the green space through evapotranspiration (J/(m^3 × h))

P_C: the volume heat capacity of the air (1256 J/(m^3 × ˚C))

ΔT: the decreased air temperature (˚C)

A_i: the area of the urban green infrastructure

To alleviate the discomfort caused by the high-temperature environment in the city, residents usually use air conditioners for air temperature reduction. This consumes additional power, which can be calculated using Eq. 4:

$$ES = \sum_{i=1}^{n} \alpha \cdot COP \cdot Q_i \quad (4)$$

where ES is the amount of energy saved by reducing the air temperature through the UGI. COP, i.e., the air conditioning performance coefficient, is the efficiency of the artificial cooling system, normally ranging from 2.6 to 3.2. The average value of 2.9 was used in this study (Oliveira, 2011). α represents the conversion factor for converting heat into electrical energy (1 J = 0.278 × 10^{-6} kWh).

2.3.2.2. Sites and data collection. The monitoring points and period for both air temperature and air quality were the same in three urban green spaces. The air temperature was monitored by Heat Index WBGT Meter (WBGT-2010SD), which recorded the average air temperature every half hour, and was placed in different functional areas and protected from direct sunlight.

2.3.3. Rainwater runoff regulation

2.3.3.1. Quantification method. UGI can manage urban stormwater runoff, achieve flood mitigation, and enhance water resource utilization (Zölch et al., 2017). UGI maintains regional hydrological processes by controlling land-use patterns (through green roofs, permeable pavements, and grass planting) and using a series of specific technical measures (such as ditches, vegetation filter belts, and constructed wetlands) (Raspati et al., 2017).

An important indicator of the ability of UGI to regulate rainwater is the leaf area, which is usually described by the leaf area index (LAI) (Keim et al., 2006). This study adopted the gap fraction analysis to infer the LAI by taking hemispherical photographs and measuring the light transmitted through the canopy (Smith et al., 2008). When rainwater falls from the atmosphere into a vegetated ecosystem, the canopy layer of vegetation is the first to encounter precipitation. Different tree species have different maximum rainwater storage capacities in the plant canopy. To calculate the mitigation capacity of the UGIs for rainwater runoff in the three parks, several tree species that occupied the largest proportion of planting in the parks were selected as the targets. Using one target tree as the center point, the tree group was photographed at different angles with a fisheye camera according to the outline of a rectangle. A total of eight canopy photographs were taken at each sampling point to calculate the LAI of the sampled tree species. Finally, the LAI values of the various points obtained in the same park were averaged to obtain the LAI value for each park.

The rainwater interception capacity of the plant canopy was determined by the specific water storage capacity of each vegetation type, and its LAI as expressed below:

$$S_{L(UGI)} = \sum_{i=1}^{n} P_i \cdot S_{Li} \quad (5)$$

$$S_C = LAI \cdot S_{L(UGI)} \quad (6)$$

The plant canopy capacity for rainwater storage (S_C, g/m^2) is determined by the specific water storage capacity of each vegetation type and its LAI, while S_L (g/m^2) is the potential maximum amount of the water storage per unit leaf area. According to the water storage capacity of the main tree species in the Guangzhou parks (S_{Li}) and the percentage of each tree species i (P_i), the average water storage capacity of the tree canopy in the Guangzhou parks ($S_{L(UGI)}$) can be obtained. By multiplying the values of LAI and the average water storage capacity of the tree canopy in each park, the plant canopy capacity for rainwater storage (S_C) (maximum intercepting flow rate of the leaf) corresponding to the unit of land area in the three parks can be obtained separately (Llorens and Domingo, 2007).

2.3.3.2. Sites and data collection. Several types of trees that occupy the main green area in each park were selected as the study object from which to measure LAI. For each study object, eight images were taken by digital hemispherical photography (DHP, Nikon D90 + 10.5 mm F/2.8 g ED). The digital hemispherical photographs were taken at 1.5 m above the ground. In such images, the view of the areas outside the

measured tree should not be included (Kang et al., 2005). The images were taken on cloudy days or before sunrise and after sunset to avoid interference from direct sunlight. The captured image was digitized, and the effective LAI was calculated using the analysis software CAN-EYE 6.4 by calculating the solar radiation transmission coefficient, the canopy gap size, and the gap ratio parameter (Yan et al., 2019). Fig. 3 shows the methods and measurement progression of the fisheye photographs of the sampled sites in each park. According to the analysis results, the average LAI of FCS is 1.57; HLP, 0.945; and YXP, 2.49 (Table S2).

2.3.4. Noise abatement

2.3.4.1. Quantification method. Sustained technological advances in industrialization and the expansion of the urban population produce a variety of unpleasant noises, resulting in a considerable negative impact on urban soundscapes (Zannin et al., 2002; Raimbault and Dubois, 2005; Pimentel-Souza, 1997). Noise, defined as the 'unwanted sound', is perceived as an environmental stressor and nuisance (Stansfeld and Matheson, 2003). Such unwanted sound affects human health (Stansfeld and Matheson, 2003; Babisch et al., 2005) and human behavior (Sobotova et al., 2010). Much scientific evidence demonstrates that noise exposure can induce sociopsychological responses, (such as annoyance and sleep disturbance), physical responses (such as hearing impairment, hypertension), and disturbance of daily activities and performance (Bolund and Hunhammar, 1999; Stansfeld and Matheson, 2003; Babisch et al., 2005; Sobotova et al., 2010).

Parks are considered 'quiet green' areas. The noise abatement by UGI plays an important role in the life quality of people (Szeremeta and Zannin, 2009). The foliage of trees or shrubs is similar to a sound-absorbing wall. When the sound waves pass through vegetation, the flexible leaves of trees or shrubs absorb part of the energy, thereby contributing to noise reduction (Magrab and Jackson, 1973). A study carried out in 21 urban green spaces in the city of Puebla (Mexico) indicated that both the park size and total tree canopy cover significantly influence the noise levels, irrespective of the park location and composition of tree species (González-Oreja et al., 2010). The noise reduction capability of each UGI was evaluated based on the abatement rate of the noise, and was calculated as follows (Cohen, 2003):

$$N_i = \frac{L_{0i} - L_{xi}}{L_{0i}} \times 100\% \quad (7)$$

where N_i is the noise abatement rate of park i, L_{0i} is the decibel value of the noise source in the park, and L_{xi} is the noise value when the distance from the noise source is X.

2.3.4.2. Sites and data collection. The main road outside every park was considered a major noise source. The monitoring instrument was set inside the park at 20 m from the noise source and 1.3 m from the ground. The noise source was located at the edge of the sampled park. The instrument was located at the center of the sampled site, perpendicular to the edge of the sampled park. The measurements were conducted when the plants grew vigorously, the tourists were few and the traffic was busy (9:00, 12:00, 15:00, 17:00). The noise level was recorded with Quest-pro-DL noise detectors, with a measuring range from 40 to 110 decibels, and a resolution of 0.1 decibels. Before the measurement, the noise detectors were calibrated using a QC-10 calibrator (114 dB, 1000 Hz). During the measurement, the average noise level of a running time of every one minute was automatically calculated and recorded. Each sample site has been monitored four times, and the measured results were averaged.

2.3.5. Monetary valuation

The monetary valuation of ESs is estimated to express their importance for policy and management strategies (Scholte et al., 2015). This step aims to translate the main ESs of studied UGIs into monetary terms. Through the monetary valuation method (Table S3), the valuation standards of benefits provided by different types of ESs could be unified, thus, the contribution of different types of ESs could be more intuitively reflected and compared. The total economic value (TEV) framework was used to translate ESs into monetary values. The TEV considers direct market values, indirect market values, and nonmarket values. In this study, the monetary value of air pollutant removal and noise abatement was calculated with the avoided cost (AC) evaluation method, while the monetary value of reducing the daytime temperature and rainwater runoff regulation was calculated via replacement cost (RC) evaluation method.

2.4. Ecosystem services demand (ES demand)

To investigate the public demand for ESs, a questionnaire (Table S4) survey was performed to analyze people's awareness, satisfaction, and WTP for the ESs of UGI, based on hypothetical market prices. The survey applies dichotomous choice (DC) and contingent valuation (CV) methods to collect the preference information and estimate the use and preservation (or nonuse) value of the resources in the three different parks. CV is one of the standard methods to measure the economic value of nonmarket products, such as recreational resources, historical sites, and environmental quality products (Lee and Han, 2002).

2.4.1. Questionnaire design

The questionnaire in this study contained three parts, and the details are described in the following sections.

2.4.1.1. Sociodemographic variables. The identity of the respondents can influence their understanding of the local UGI. Therefore, the sociodemographic information of the respondents was gathered, including gender, age, education level, monthly income, and birthplace). The basic background information of the respondents was collected for a more structured analysis of the statistical results. Residents and tourists were separated, and the length of time that they had lived in Guangzhou was also investigated and recorded.

2.4.1.2. Awareness and satisfaction. The second part of the survey was about the respondent's subjective evaluation of the study sites (FCS, HLP, YXP). Respondents' satisfaction with the green space of the study area was divided into five levels, from very satisfied to very unsatisfied. The shortage of existing green space in the surveyed park was set as an open-ended question to understand the respondents' demand for park green space. The purpose of visiting the park was also an important part of the questionnaire, since it reflected the respondents' inclination to enjoy the different kinds of urban ESs. Other questions regarding the frequency of visits and time spent visiting the park and the commute time were also included. In addition, ten different ESs were listed: aesthetics, entertainment, artistic design, cultural heritage, educational opportunities, reduction of the urban heat island effect, air quality improvement, urban drainage system, economic benefits, and gene pool protection. The respondents were asked to evaluate whether the park provides these ESs, and six options were provided (0 = Disagree, 1 = Partially agree, 2 = Agree, 3 = Strongly agree, '?' = Maybe, 'X' = I do not know). The respondents evaluated each ES based on their subjective experiences in the park.

2.4.1.3. Willingness to pay (WTP). The respondent's WTP for the ESs of the UGIs in the study sites was assessed via CV, which is a commonly applied method in the field of environmental analyses (Mitchell Robert and Carson, 1989) city greening (Jim and Chen, 2008; Lo and Jim, 2010), air quality (Wang and Zhang, 2009), tourism (Li et al., 2010), and ecological system services (Turner et al., 2000; Laughland et al., 1996). Respondents were asked to state the maximum amount of money they are willing to pay to maintain the UGIs. The reason for refusing would also be asked to respondents who were unwilling to pay.

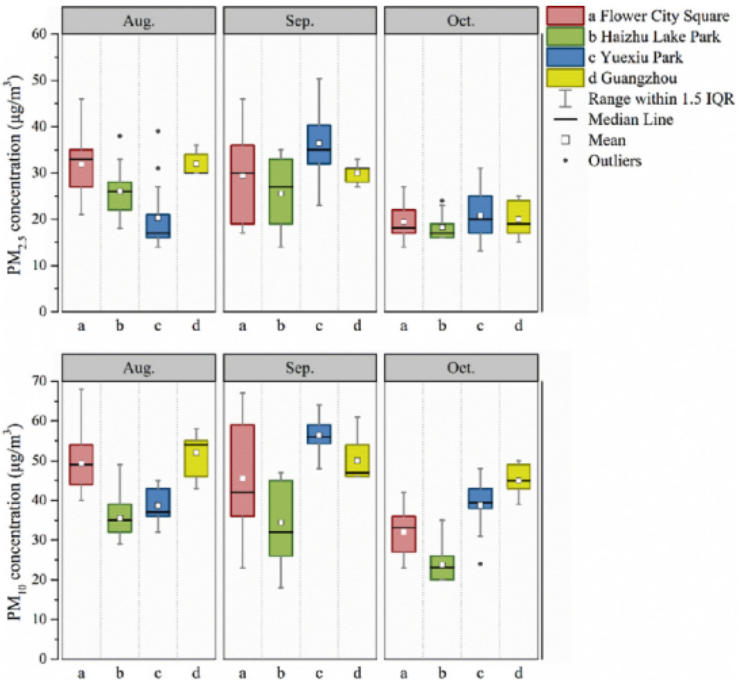

Fig. 4. Monthly values of $PM_{2.5/10}$ measured in the three parks and from the Guangzhou Meteorological Bureau in the summer of 2018 ($\mu g/m^3$).

According to the frequency distribution of the respondents' WTP, the means of the WTP can be obtained by the expectation formula for discrete variables (Einarsdóttir et al., 2019; Mcgurk et al., 2019):

$$\overline{E}(WTP) = \sum_{i=1}^{n} (A_i P_i) \quad (8)$$

where A_i is the bidding value, Pi is the possibility of the respondent choosing the bidding value, n is the bidding group, and in this case, n = 10 (RMB 0, 1−0, 1–5, 5−5, 5−10, 10–50, 50–100, 100–200, 200–300, 300–500, 500–700, 700+).

2.4.2. Questionnaire distribution

To explore the particular issues that may potentially have an antagonistic impact on the survey results, a pilot survey was conducted in Sun Yat-sen University, but the answers of the pilot survey were not included in this study. Questionnaires were conducted in three urban parks, and the gender and age balance of the respondents was maintained. Each respondent completed the questionnaire independently and without interference, and we provided relevant information and explanations in a timely manner to ensure that the respondents fully and clearly understood the meaning of each question. For the questionnaire survey, based on the 95 % confidence level, 5% confidence interval and Guangzhou population, the sample size was calculated to be approximately 400 (Raosoft, 2013). From September to October 2018, 420 questionnaires were distributed in the three parks. In each park, 135 valid questionnaires were collected, and a total of 405 valid questionnaires were completed.

2.5. Statistical analysis

To extract useful information and obtain conclusions, the questionnaire response data and the measurement data of the air quality were studied and summarized in detail by statistical analysis methods. The study locations, visiting frequency, length of stay, commuting time, and sociodemographic variables were statistically described. After the statistical description of respondents' satisfaction with the park's green infrastructure, the nonparametric Kruskal-Wallis H test (Kruskal and Wallis, 1952) was applied to study the differences among these reactions, as these concerns were ordinal and not normally distributed. The differences were checked by considering the study locations, demographic variables, and use of space. Further, the relationships among people's responses and their sociodemographic characteristics, commuting time, length of stay time, and frequency of visits were explored by using a binary logistic regression model (Hilbe, 2011). Before applying the regression analysis, the two response scales were simplified to 'yes = 1' and 'no = 2'. The preliminary experiments were carried out to select the relevant sociodemographic variables and exclude other parameters from the regression. The Hosmer-Lemeshow test was applied to assess the goodness-of-fit of the model (Hosmer and Lemeshow, 2000). The analysis of the respondents' perspective about the ESs of UGI was further analyzed by a cross-tabulation analysis (De Vaus, 2002), which is needed to grasp the data distribution of different values of multiple variables to further analyze the interaction and relationships among the variables (Cohen et al., 2014). The sociodemographic characteristics were the same as the parameters in the logistic regression analysis.

3. Results

3.1. Results of ES supply

3.1.1. Air pollutant removal

The average values of $PM_{2.5}$ and PM_{10} measured in the three parks per hour can be used to obtain the average concentrations of inhalable particulate matter in each park in the summer. In addition, the monthly air pollutant concentrations in Guangzhou in summer 2018 were obtained from the air quality measurement by the Guangzhou Meteorological Service (Guangzhou Meteorological Service, 2018) (Fig. 4). Using Eq. 1, the concentration reduction and purification rate of $PM_{2.5}$ and PM_{10} were calculated based on the meteorological station data and the measured data (Table 1).

Table 1
The concentration reduction and purification rate of $PM_{2.5/10}$ in the three parks in the summer of 2018 ($\mu g/m^3$).

Parameters	Flower City Square		Haizhu Lake Park		Yuexiu Park	
	$PM_{2.5}$	PM_{10}	$PM_{2.5}$	PM_{10}	$PM_{2.5}$	PM_{10}
Average concentration ($\mu g/m^3$)	26.87	42.07	23.26	31.26	25.84	44.45
Concentration reduction ($\mu g/m^3$)	0.46	5.93	3.47	11.32	1.42	4.13
Purification rate(%)	1.7	14.1	14.9	36.2	5.5	9.3

The purification rates of the $PM_{2.5}$ and PM_{10} in HLP were the highest among the three parks. In HLP, the $PM_{2.5}$ can be reduced by 3.47 micrograms per cubic meter. The purification rate of $PM_{2.5}$ in HLP is 14.9 %, which is 8.8 times higher compared to that in FCS. Additionally, the purification rate of PM_{10} in HLP reached 36.2 %, which was close to 4 times of that in YXP.

3.1.2. Daytime air temperature reduction

In this study, daytime air temperature measurements were carried out in the three parks in different functional areas (a shaded area, waterside area, and lawn area). The average reduction in the daytime air temperature in each park was obtained by comparing the air temperature measurements with the data from Guangzhou Meteorological Station (Fig. 5). Among the three sites, HLP showed the greatest ability to reduce air temperature. The average reduction of daytime temperature in this site decreased by 2.32 °C, followed by 0.58 °C in FCS and 1.38 °C in YXP. Similar to air temperature reduction, the energy saved by the reduction of air temperature was also the highest in HLP (Table 2).

3.1.3. Rainwater runoff regulation

In this study, the rainfall interception ability of vegetation at each research site was calculated based on the rainfall canopy interception principle and LAI. Different tree species have different maximum canopy rainwater storage capacities.

Several tree species are popular in Guangzhou parks, including Ficus altissimo (Ficus lacor Buch. Ham.), Ficus microcarpa (F. retusa Linn.), Michelia alba (Michelia alba DC.), Magnolia grandiflora (Magnolia grandiflora L.), and Kapok (Gossampinus malabarica (DC.) Merr.). The occurrence frequency of most of these common tree species in Guangzhou was above 20 % (Jim and Liu, 2001). According to the occurrence frequency of the common tree species in Guangzhou and the percentage and potential maximum water storage capacity of these tree species in the parks, the average maximum rainfall interception of the urban green space in the Guangzhou parks ($S_{L(UGI)}$) was estimated to be 83 – 98 g/m² (Table 3) (Herwitz, 1985; Jim and Liu, 2001).

The LAI of the vegetation in the three parks was measured and recorded. The green area of the FCS covers 560,000 square meters, the green area of YXP covers 690,000 square meters, and the green area of HLP covers 420,000 square meters. According to Eq. 5, the total rainwater interception in the plant canopy of the UGI in each park was calculated. The result showed that YXP had the greatest capacity for rainwater interception, being 155,615 kg (Table 4). This means that YXP could reduce the largest amount of rainwater runoff compared with that of the other two parks.

3.1.4. Noise abatement

In this study, according to the noise measurement data, we can determine the extent to which the decibels were reduced and obtain the reduction rate of the noise in the different UGIs (Fig. 6). Although the noise sources of each park are different, YXP was more capable of controlling noise than the other two parks. Using the average noise decibels reduction value from four different time points in every park, the ability of noise abatement in each park was obtained. YXP had the largest noise reduction (5.53 decibels), with a noise abatement rate of 8.2 %. The noise abatement rate reached 7.2 % in HLP, where the noise level was decreased by 4.28 decibels. FCS had the weakest ability to reduce noise, with only a 3.95 decibels noise reduction and 6.9 % noise abatement rate.

3.1.5. Monetary valuation

The benefits of the different ESs could be better compared by the monetary value methods. Compared with the major ESs, the daytime air temperature reduction provided the highest monetary value followed by the rainwater runoff reduction. Among the three urban green spaces, YXP provided the highest monetary value of the main regulation services (Table 5).

The air quality regulation service had a direct market value, while the AC monetary valuation method is often used to assess the monetary value of this service. Based on the marginal emission reduction cost of $PM_{2.5}$ and PM_{10}, i.e., 0.185 and 0.37 RMB/kg, respectively (Jim and Chen, 2008), the total annual value of the air pollutant removal by the UGIs in the three parks was estimated (marginal emission reduction cost of each pollutant multiplied by the amounts of each air pollutant removed) to be approximately 27,500 dollars in 2018.

The RC monetary valuation method was used to calculate the monetary value of the daytime temperature reduction service of the UGIs. According to the residential electricity price of 0.5 RMB/kWh (Jia

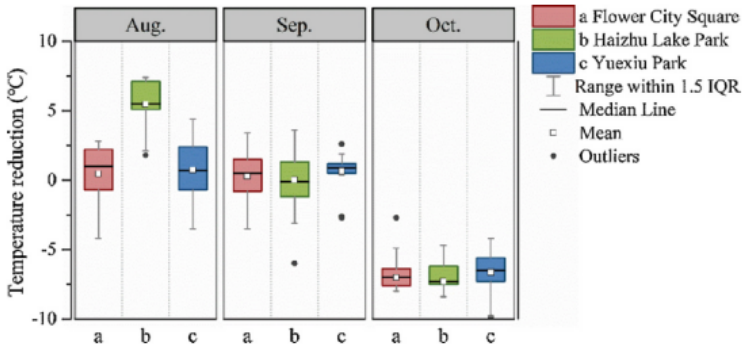

Fig. 5. Daytime temperature reduction measurement data from the three UGIs from August to October.

Table 2
The average daytime temperature, heat, and energy power reduction data from the three parks.

Parameters	Flower City Square	Haizhu Lake Park	Yuexiu Park
Average temperature reduction (°C)	0.58	2.32	1.38
TQ ($*10^7$ J/d)	490	1469	1435
ES (kwh/d)	3947	11,840	11,570

Table 3
Water storage capacity of the common tree species in all of Guangzhou.

Tree type	Occurrence frequency	Percentage (%)	S_L (g/m²)
Ficus altissimo	39 %	51.3 %	100–120
Ficus microcarpa	30 %	–	–
Michelia alba	11 %	14.5 %	30–40
Magnolia grandiflora	26 %	34.2 %	80–90
Kapok	24 %	–	–
$S_{L(UGI)}$			83–98

Table 4
Total rainwater interception in the three parks.

Parameters	Flower City Square	Haizhu Lake Park	Yuexiu Park
LAI	1.57	0.945	2.49
$S_{L(UGI)}$ (g/m²)	83 ~ 98		
S_C(g/m²)	130 ~ 154	78 ~ 93	207 ~ 244
Green area (m²)	560,000	420,000	690,000
Rainwater interception (kg)	79,635	35,948	155,615

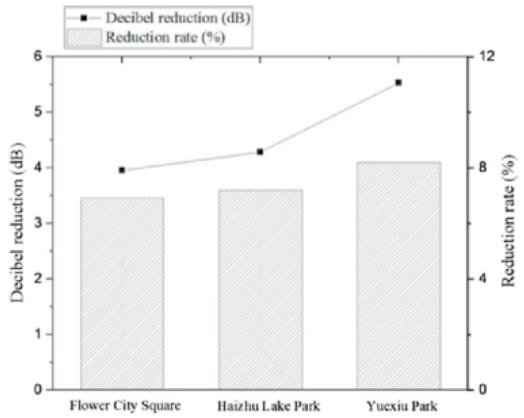

Fig. 6. Reduced decibel and the reduction rate of noise in three parks.

and Qiu, 2017), the monetary value of reducing the daytime air temperature for one year in the three parks was calculated. The yearly monetary value of reducing the daytime temperature by the UGIs in the three parks was $735,000/y, while HLP had the highest monetary value of ES.

The monetary value of the rainwater storage service of the green spaces was also estimated by using the RC monetary valuation method. The economic benefit of rainwater storage can be regarded as the replacement cost of reservoirs, and its value can be calculated by the volume and unit cost of a reservoir. In recent years, the cost of water storage units in China has risen to 7.73 RMB/m^3 (Zhang et al., 2010). In addition, the quality of rainwater runoff after passing through UGIs is better than that of the runoff from the pavement (Teemusk and Mander, 2007). The rainwater runoff in the UGIs is often used as reclaimed water for greenfield irrigation and car washing. Therefore, the cost of runoff purification can be saved in areas with UGI. This value, calculated from the quantity and price of reclaimed water, was estimated to be 1 RMB/m^3 in China according to Liu and Chu (2007). In this study, the total value of rainwater runoff management services in the three parks reached $48,000–56,000/y, with YXP being the main contributor.

As an economic lever that encourages enterprises to take measures to reduce pollution, the Chinese government implemented a system of noise pollution discharge and compensation fees in the National Noise Pollution Prevention Law (Ministry of Environmental Protection of China, 2011). The actual amount of compensation depends on the negotiation between the contractor and the neighbor, and an average value of 1 dB above the limit was equal to approximately 45 RMB per month (Xiao et al., 2017). According to the AC monetary valuation, the monetary value of the noise abatement in the three urban green spaces was estimated as $32,000 per year.

3.2. Results of ES demand

3.2.1. Profile of the respondents

Table 6 lists the profiles of the respondents in this study. The proportion of tourists in UGIs accounted for 34.6 %, which indicates that Guangzhou is a popular city for tourists. Respondents had a balanced male-female ratio, making the data analysis of this survey more justified. Most of the respondents were young, and the people who were over 60 years old accounted for only 7.2 % of the total respondents. More than 59 % of respondents had a bachelor's degree or higher. Of all the respondents, 83.7 % lived in Guangzhou for more than a year, while approximately 47 % lived in Guangzhou for more than 10 years. A total of 27 provinces and municipalities in China were mentioned in the survey. More than half of the respondents were born in the Guangdong Province (52.6 %).

Various reasons for visiting these three city parks were revealed from the survey, with 'relax and enjoy the environment' being the most common one. The majority of the respondents went to FCS for parties (21.5 %) and shopping (19.2 %). Many people passed by FCS because it is the transportation hub and financial center of Guangzhou, with multiple transportation facilities, are close by. The most popular

Table 5
Annual monetary value of the main regulation services ($) in the three UGIs in 2018 in Guangzhou (US $1.00 = RMB 6.79).

Green spaces	Air pollutants		Daytime temperature	Rainwater runoff	Noise abatement	Total
	$PM_{2.5}$	PM_{10}				
Flower City Square ($/y)	200	7000	106,000	15,500	9000	137,700
Haizhu Lake Park ($/y)	1400	13,000	318,000	6500	10,000	348,900
Yuexiu Park ($/y)	900	5000	311,000	29,500	13,000	359,400
Three parks ($/y)	2500	25,000	735,000	51,500	32,000	846,000

Table 6
Sociodemographic variables of the respondents.

Sociodemographic category	Variables	Flower City Square		Haizhu Lake Park		Yuexiu Park		All
		N	(%)	N	(%)	N	(%)	(%)
Identity	Resident	98	(72.3 %)	90	(66.9 %)	75	(55.9 %)	65.4 %
	Tourist	37	(27.7 %)	45	(33.1 %)	58	(43.1 %)	34.6 %
Gender	Male	60	(44.6 %)	64	(47.7 %)	70	(51.5 %)	47.9 %
	Female	74	(55.4 %)	71	(52.3 %)	65	(48.5 %)	52.1 %
Age	15 – 24	28	(20.8 %)	38	(28.5 %)	22	(16.2 %)	21.8 %
	25 – 29	27	(20.0 %)	20	(14.6 %)	20	(14.6 %)	16.4 %
	30 – 49	66	(49.2 %)	48	(35.4 %)	62	(46.2 %)	43.6 %
	50 – 59	9	(6.9 %)	21	(15.4 %)	15	(10.8 %)	11.0 %
	≥60	4	(3.1 %)	8	(6.2 %)	17	(12.3 %)	7.2 %
Education level	Middle	15	(10.8 %)	31	(23.1 %)	27	(20.0 %)	17.9 %
	Senior	24	(17.7 %)	42	(30.8 %)	28	(20.8 %)	23.1 %
	Bachelor	83	(61.5 %)	55	(40.8 %)	69	(50.8 %)	51.0 %
	Master	11	(8.5 %)	7	(5.4 %)	10	(7.7 %)	7.2 %
	PhD	2	(1.5 %)	0	(0.0 %)	1	(0.8 %)	0.8 %
Time category	< 1 year	20	(15.0 %)	28	(20.9 %)	18	(13.1 %)	16.3 %
	1≤ t < 5	31	(23.6 %)	23	(17.1 %)	28	(20.8 %)	20.5 %
	5 ≤ t < 10	26	(18.9 %)	24	(17.8 %)	17	(12.3 %)	16.3 %
	≥10 year	57	(42.5 %)	60	(44.2 %)	73	(53.8 %)	46.9 %

location for physical exercises and group activities is HLP. Several lakes in this park offer more options for sporting activities, such as racing around the lake and rowing. Compared with the other two parks, YXP had the highest total proportion (approximately 20 %) of respondents who participated in cultural-artistic creation and popular science exhibitions. In addition, the vast majority of respondents (82.5 %) spent no more than an hour in the three parks, and the frequency of the park visits of the respondents was diverse and evenly distributed.

3.2.2. Awareness of UGIs' ESs

The users' awareness of UGIs' ESs could guide the government's policy on urban construction and the environmental education activities organized by international environmental non-governmental organizations. The survey listed ten kinds of common ESs and allowed respondents to rank them based on their feelings in the study areas. According to the statistical analysis, the relevant ratios were obtained. Respondents in the three parks had the highest approval rates for the aesthetically pleasing views (Fig. 7). More than 95 % of the respondents in each park described that the visited green space met their personal aesthetic needs, while over 85 % of the respondents expressed that the UGI is a good place for recreation. For cultural values, respondents in YXP presented the most positive response, with 81.5 % saying that the UGI gave inspiration to their cultural or artistic creations, while 93.8 % of the respondents believed that YXP is a 'bridge' of cultural heritage. It is worth mentioning that FCS was considered to be the most educational place, and 83 % of respondents believed that it can provide opportunities for outdoor classrooms and research investigations. In total, 87.1 % and 91.3 % of respondents strongly agreed that UGI in the three parks can effectively alleviate the urban heat island effect and purify the air quality. However, the approval rate for the ability to reduce the pressure on urban drainage systems accounted for only 72.8 %, which has declined dramatically compared to the approval rate of the other regulation services. Moreover, 29.3 % and 25.9 % of respondents expressed uncertainty or ignorance about the ability of UGI to bring economic benefits to Guangzhou and protect genetic diversity.

3.2.3. Satisfaction with the UGI situations

The responses to the questions that were raised to address the satisfaction of the respondents to the current UGIs' status quo in all survey locations were integrated. Among the three UGIs, FCS had the highest satisfaction (84.6 %), followed by HLP (81.5 %) and YXP (71.5 %). In total, the results showed that 79.2 % of the respondents were satisfied and very satisfied with the status quo of the UGI in Guangzhou. Only 1.5 % of respondents expressed dissatisfaction with the UGI in Guangzhou, and no one was very dissatisfied (Fig. 8). These results imply that the greening of urban parks in Guangzhou basically meets the daily needs of people and was highly praised by the users.

3.2.4. Willingness to pay (WTP)

According to the statistics, 45.1 % of the respondents in all three parks were willing to pay for maintaining the UGIs. In comparison, among the three parks, only HLP had more than half of the respondents who were willing to pay (50.8 %). The reasons for refusing to pay were also investigated through the questionnaire. Nearly half of the reasons for the refusal to pay were because the respondents believed that the construction fees of the UGI should be paid by the government. In addition, 29.5 % of the respondents felt the park is too far, 25.3 % of the respondents preferred indoor activities, 18.9 % of the respondents said that they have a limited income, and 9.2 % of the respondents worried that the cost of payment cannot be properly applied to the UGI. At the same time, more than one-fifth of the respondents who refused to pay expressed that they have no concern about the urban ecosystem.

Using the CV monetary valuation method, the results of the questionnaire showed how much the respondents are willing to pay for the ESs provided by the UGI in the three parks each year. In total, approximately 45.1 % of the respondents were willing to pay for the ESs provided by the UGI. In total, 31.2 % of the respondents were willing to pay 0 ~ 50 RMB (US $1.00 = RMB 6.79; $0 ~ 7) per year, 9.8 % of respondents were willing to pay 50 ~ 200 RMB ($7 ~ 29) per year, 2.6 % were willing to pay 200 ~ 500 RMB ($29 ~ 74) per year, only 1.5 % were willing to pay more than 500 RMB ($74) per year, and no one was willing to pay more than 700 RMB ($103) per year. The survey results about the WTP in three parks can be calculated by Eq. 8. The population of Guangzhou reached 14.49 million in 2018 (World Urbanization Prospects, 2018). According to the respondents' WTP, the monetary value of the ESs was estimated to be 216,000–436,000 thousand dollars per year for the three parks (Table 7).

3.3. Comparison between the ES supply and demand

3.3.1. Satisfaction with the UGI situation, WTP &ES supply

Interestingly, several mismatches among people's satisfaction, WTP, and the benefits provided by the UGI could be observed. According to the questionnaire analysis, FCS was the place where the respondents expressed the highest satisfaction, followed by HLP and YXP. However, HLP received the most positive responses when respondents were asked

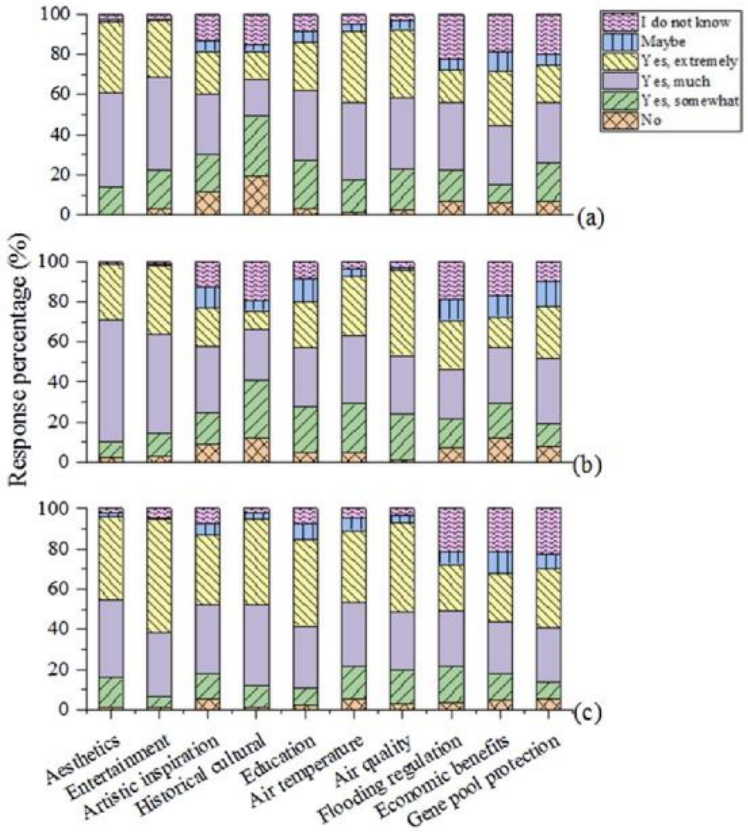

Fig. 7. Responses percentage of the awareness of ESs provided by the UGIs (a. FCS, b. HLP, and c. YXP).

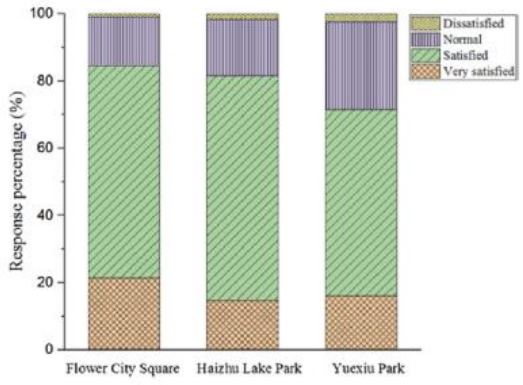

Fig. 8. The percentage of the satisfaction level of the UGI.

if they were willing to pay for the ESs provided by the UGI. Such proportion reached over 50 % of the respondents. Furthermore, according to the field measurements, the benefits provided by the regulation services of YXP were the maximum among those of the three UGIs. At the same time, the UGI in YXP was also considered to provide the most cultural values. Compared with the other two parks, YXP contained the highest total proportion of respondents who participated in artistic creation and popular science exhibitions.

3.3.2. People's awareness and the ES benefits

Cognitive gaps between people's awareness of the ESs and the benefits provided by the UGIs were revealed. People tended to make the most positive responses to the ESs closely related to real life. For example, several cultural services (e.g., aesthetics, entertainment value, and educational aspects) were more likely to be directly perceived by the respondents. These services were also the reasons why most of the respondents came to visit the UGIs. Second, people often estimate the regulation services provided by the UGI based on their cognition and knowledge. The majority of the respondents believed that UGIs can improve air quality and daytime temperature. However, they often neglected the ability of UGI has the ability to alleviate ground runoff and reduce noise.

Table 7
Willingness to pay (WTP) and the monetary value of the annual ecosystem services (ESs) in the three parks.

Parameters	Flower City Square	Haizhu Lake Park	Yuexiu Park	All locations
Willing to pay (%)	43.8 %	50.8 %	40.8 %	45.1 %
Willing to pay ($/person/y)	5–9	5–10	4–11	14–20
Monetary value (thousands/y; ($))	103,000	113,000	109,500	326,000

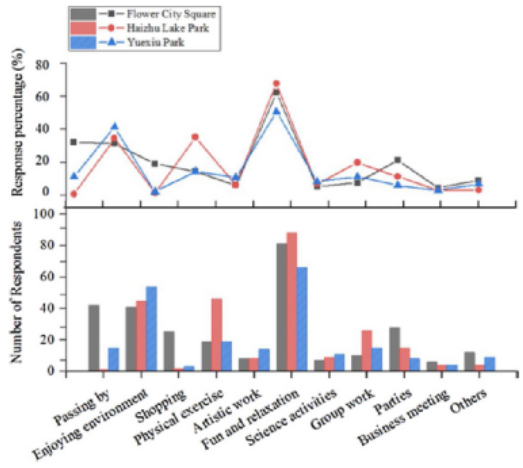

Fig. 9. Number of respondents and the percentage of purposes for visiting the UGIs in the three parks.

3.3.3. Factors affecting public ES demand

In this study, the uncertainty and inaccuracy of people's perception of the ESs were discovered by comparing the measurement data and the questionnaire survey of the UGI users. To understand the factors affecting people's perception, the sociodemographic characteristics of the respondents, the frequency, time of stay, commuting time and purposes of visiting the UGI were analyzed.

The results showed that most people would like to visit UGIs to enjoy the environment and have fun (Fig. 9). The gender ($p = .049$) of the respondents and the length of time the respondents lived in Guangzhou ($p = .002$) significantly influenced their satisfaction with the UGIs (Table 8). In general, females showed more positive attitudes about UGIs. The longer people lived in Guangzhou, the higher their satisfaction level of the UGIs was. At the same time, According to the cross-tabulation analysis (De Groot et al., 2002), the respondents who lived in Guangzhou for more than 10 years and were satisfied and very satisfied with the UGIs accounted for 36.2 % of the total responses. Most of the respondents who lived in Guangzhou for a long time turned out to be residents. Comparing the respondents from three UGIs, the residents accounted for the highest proportion (72.3 %) of the respondents in FCS. In addition, the respondents who went to the parks for the 'entertainment and passing by' were more likely to be satisfied with the ESs of the UGIs. The majority of the respondents in FCS were at the UGI for these two purposes, and accounted for the highest proportion (95.4 %) among the three UGIs. The respondents who had lived in Guangzhou for a long time and the visitors who had 'no purpose' with a relaxed mood, had a more positive evaluation of the current situation of the UGI; therefore, the satisfaction of the UGI was higher.

The nonparametric Kruskal-Wallis H test and a binary logistic regression model were applied to further analyze the relationship between the sociodemographic variables and people's WTP. Identity was determined to be a significant factor affecting people's WTP ($p = .02$) (Table 9). The residents were more willing to pay for Guangzhou UGI compared with the tourists. This is probably because that residents can enjoy the ESs provided by the UGI for a longer time. In addition, the frequency with which the UGIs' users accessed the green space had a significant impact on people's WTP ($p = .000$). According to the logistic analysis, UGI users who visited green space every week were more willing to pay for ESs. Among the three parks, most of the respondents visited HLP weekly. When the frequency of visits decreased, people's WTP also decreased. Furthermore, education ($p = .0164$) and commuting time ($p = .0444$) had significant impacts on WTP. When the commuting time was within two hours and the more time people spent on transportation, respondents were willing to pay more money for the UGI. Most of the respondents in HLP had commuting times within 30 – 120 min. Compared with the other two parks, more commuting time was spent by the respondents to visit HLP. Moreover, the respondents who enjoyed the environment and physical exercise were more likely to pay for the UGI. HLP was considered to be the most suitable place for physical exercise, and most respondents came to HLP because they wanted to enjoy the environment and exercise. When people choose whether to pay or not, they were often influenced by the time and cost of their investment and whether they could obtain immediate benefits. In other words, within a reasonable range, people are more willing to pay for a two-way choice mode.

4. Discussion and conclusion

4.1. Differences between ES supply and demand

Through the investigation of ES supply and ES demand, the proportion of market value brought by regulation service in the ES provided by the existing UGIs was revealed to be the highest, However, the respondents paid more attention to and preferred to the cultural service.

According to the real-time measurement and questionnaire analysis, YXP provided the most regulation services with the highest monetary value ($359,400/y) in the three public green spaces. However, people were most satisfied with FCS, with more than 85 % of the respondents expressing satisfaction. In addition, people have the highest WTP for ESr in HLP, reaching $113,000 per year.

People had varying criteria for and influencing factors of their ES demand. Although YXP supplied the highest monetary value of ESs in the market scenario. UGI's users were more likely to be satisfied with the urban green space that could provide more educational opportunities, and were more willing to pay for UGI which could provide more entertainment and leisure opportunities and health value. Moreover, public demand for UGI affected their perception of different types of ESs. Compared with the 'invisible' regulation service, people pay more attention to the aesthetic value and entertainment value. Besides, the purpose of visiting the UGI and some sociodemographic variables had significant impacts on people's satisfaction and WTP for the UGI. Knowledge gaps and social needs led to a certain degree of deviation between people's perception of the UGI and the actual benefits of the ESs.

Table 8
The p-value from the Kruskal-Wallis H test for the satisfaction of the UGIs.

Sociodemographic variables	Identity	Gender	Age	Time living in Guangzhou	Education level	Income	Frequency	Length of stay	Commuting time	Purpose of the visit
Flower City Square	0.546	0.247	0.570	0.898	0.176	0.972	0.396	0.218	0.167	0.231
Haizhu Lake Park	0.026*	0.449	0.050*	0.000**	0.213	0.007**	0.011*	0.380	0.259	0.583
Yuexiu Park	0.482	0.427	0.338	0.118	0.977	0.677	0.778	0.503	0.088*	0.174
All locations	0.925	0.049*	0.785	0.002**	0.537	0.103	0.424	0.203	0.542	0.447

* Indicates significance at the 0.05 level.
** Indicates significance at the 0.01 level.

Table 9
The p-value from the binary logistic regression analysis for the WTP for the ESs.

Sociodemographic variables	Identity	Gender	Age	Time living in Guangzhou	Education level	Income	Frequency	Length of stay	Commuting time	Purpose of the visit
Flower City Square	0.101	0.600	0.339	0.257	0.011*	0.557	0.007**	0.198	0.619	0.123
Haizhu Lake Park	0.453	0.447	0.622	0.090	0.001*	0.425	0.469	0.988	0.455	0.656
Yuexiu Park	0.165	0.022*	0.827	0.232	0.288	0.580	0.024**	0.638	0.001**	0.078
All locations	0.029*	0.214	0.914	0.900	0.016*	0.324	0.000**	0.319	0.044*	0.364

* Indicates significance at the 0.05 level.
** Indicates significance at the 0.01 level.

4.1.1. Difference ES demand in location (the type of UGI)

Overall, the respondents' ES demand from the three parks had a consistent trend towards the benefits of the ESs provided by the UGI. People attach importance to the kind of UGI which could supply more educational opportunities, entertainment opportunities, and health value. Different priorities can also be observed in people's satisfaction and willingness to pay for UGI.

People were more satisfied with the UGIs that can provide more educational opportunities. With the development of urban civilization, public demand for cultural services is also growing. With many museums, theaters, and libraries and a variety of science and technology exhibitions, FCS was considered to be a new multifunctional urban park that offers more educational opportunities. The respondents had the highest satisfaction with this park (85 %) compared with that of the other two.

People were more willing to pay for the UGI that can provide more entertainment and health value. HLP was considered to be the most suitable place for recreation. More respondents believed that HLP had effectively improved the air quality and matched their appreciation of aesthetics, mainly because of the larger area of water body in HLP compared to that in the other parks. Watkins et al. (2007) and Xu et al. (2011) noted that when the water area in a park increases, people's comfort is higher.

4.1.2. Difference ES demand in awareness

People had varying degrees of sensitivity to the different types of ESs provided by the UGI. Since most of the respondents were with insufficient education background of relevant environmental issues, people's awareness of the ecosystem benefits provided by the UGI was not either objective or scientific. The majority of people perceived cultural services as the most important services, followed by regulation services. Habitat services and provision services were often overlooked by some interviewees. This finding is in agreement with existing studies (Martín-López et al., 2012; Agbenyega et al., 2009; Hartter, 2010). People were more likely to perceive their immediate needs, such as aesthetic pleasure and entertainment. YXP was considered a 'bridge' between history and culture, which is due to the prosperous historical background and constructions with a long history. With the popularization of education and the media, the proportion of cultural services in people's well-being has constantly increased (Mcdonald et al., 2010; Kroll et al., 2012). In terms of regulation services, people were more sensitive to the services related to their daily lives, such as air quality. However, according to the field measurements, urban green spaces made more prominent contributions to rainwater runoff and temperature regulation, rather than air quality improvement. Moreover, many respondents had an insufficient understanding of biodiversity conservation in urban green space due to a lack of relevant information. For example, less than 70 % of the respondents agreed with the economic benefits of the UGI and the protection of the gene pool. In addition, as the provision services of the UGIs gradually weakened in the development of urbanization, most of the respondents were less likely to perceive this kind of service.

4.1.3. Influence factors of ES demand

Various factors would cause an influence on people's perception of ESs. Often, the ES that people feel satisfied with is not the same as the ES that people are willing to pay for. This research found that most of the respondents were satisfied with the status of the UGI, but less than half of the respondents were willing to pay for the ESs provided by the UGI, probably due to the demographic variables of the respondents. Such finding was consistent with those reported in other studies (Martín-López et al., 2012; Mensah et al., 2017; Petrosillo et al., 2007). Based on the nonparametric Kruskal-Wallis H test, the sociodemographic variables strongly affecting the respondents' satisfaction and the WTP were determined to be demographic characteristics, frequency of visits, the purpose of the visits, and time living in Guangzhou.

Gender had a significant impact on respondents' satisfaction with the UGI. Overall, women were more satisfied than men with the status of the UGI, suggesting that women could be more pleased to be exposed to the natural environment and have a more positive attitude towards the UGI. The plausible explanation for this pattern is that women were more sensitive to environmental pollution in cities. This explanation is supported by previous studies (Miller et al., 2007; Slama et al., 2008), which reported higher sensitivity of women toward the natural environment.

The length of time living in Guangzhou was also an important factor affecting people's satisfaction with the UGI. The results showed that respondents who lived there longer gave a higher rating for the UGIs. A plausible reason for this finding could be that the residents who have lived in Guangzhou for a long time could enjoy the benefits of the ESs provided by the UGI more easily and more sustainably. A study by Terkenli and Sarantakou (2019) also noted that respondents who lived in cities for shorter times were more likely to be tourists, thereby enjoying fewer ESs than the residents enjoyed. Fig. 10 displays the flow of the respondents in gender, length of time living in Guangzhou, and their satisfaction with the UGI.

Identity had a significant impact on whether people were willing to pay for the ESs provided by the UGI. According to the results, residents

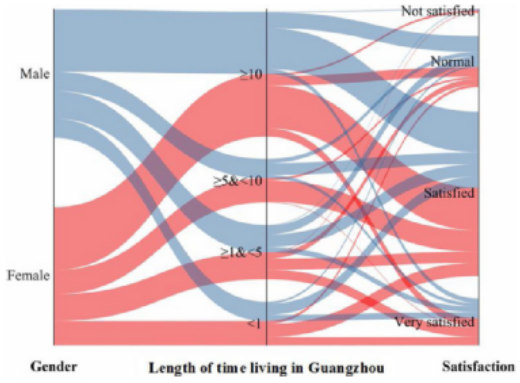

Fig. 10. The flow of respondents in gender, length of life, and their satisfaction with UGI.

were more willing to pay. Similar to the length of time living in Guangzhou, residents could enjoy more ESs provided by the UGIs; hence, they were more willing to pay for the ESs provided by the UGIs.

Education was an important factor affecting the willingness of the respondents to pay. This finding suggested that respondents with higher levels of education were more willing to pay for ESs. The proportion of respondents who responded positively to the ESs in FCS was higher than that of the other two parks. This is probably because FCS is located in the economic center and has gathered more highly educated people. The respondents with a higher education background might have a better understanding of the environmental status. Thus, they are more likely to present a positive response to the services provided by the ecosystem. Lewan and Söderqvist (2002) confirmed this result in a cognitive survey of knowledge and ESs. This finding implies that the more highly educated respondents are more concerned about the environment, and they could also have higher wages and a stronger ability to pay.

The frequency of visits also had a significant impact on the WTP. When respondents visit the UGIs more frequently, their WTP increases. Maas et al. (2009) and Mitchell and Sackney (2009) noted a strong relationship between green areas and visitors' perceptions of their health. The plausible explanation is that the respondents believed that spending more time in green space would be more beneficial to their health, and they were more willing to pay for the health benefits.

Commuting time had a certain impact on the willingness of the respondents to pay. Within a certain distance, people were more willing to pay for the UGI compared with the WTP of people who needed to spend more time commuting. This finding reveals that people turned to believe that UGIs away from the city could be more valuable and provide more ESs. When people considered that they could enjoy more ESs, they were more willing to pay for the UGI.

4.2. Limitations and recommendations of research

4.2.1. Survey process

Since the questionnaires were conducted in three parks, the respondents were all UGI users and enjoyed the ESs provided by the UGI. In fact, because a large number of questionnaires were not distributed throughout Guangzhou, the scope of the survey respondents should be extended to the entire city of Guangzhou, and the validity and reliability of the research needed to be ensured. Compared to some residents who had never visited city parks, the UGI users were more aware of the ESs and were more willing to participate in related investigations. Moreover, the differences in perceptions and comprehension of the ESs among people in densely populated urban areas should also be considered.

In addition, the majority of respondents were young, and only 7.2 % of respondents were over 60 years old. However, according to the census data, more than 29 % of the urban residents in Guangzhou were over 60 years old (Guangzhou Statistics Bureau, 2018). The main reason for the age distribution of respondents is that older people were more likely to refuse to finish the questionnaires. Many elderly people lack relevant background knowledge and cannot correctly understand the content of the questionnaire. At the same time, the proportion of elderly respondents in FCS was the smallest, because more young people like to gather in the city's economic center. Furthermore, more than 59 % of the respondents had an undergraduate degree or above, which is much higher than the census data (25 %) (Guangzhou Statistics Bureau, 2018). People with a high degree of education may pay more attention to the environment.

4.2.2. Real-time measurements

The field measurements of the air quality and temperature were conducted in the three parks from August to October 2018, with different functional areas selected as study points for each park. Only $PM_{2.5}$ and PM_{10} were considered in this study. Air pollutants can also include a variety of volatile organic compounds, hydrocarbons, ozone, toxic substances, etc. (Kampa and Castanas, 2008). Moreover, other small vegetation types, such as shrubs and lawns, had not been considered for rainwater runoff regulation. For the calculation of noise abatement, the attenuation of sound with distance should be taken into account. For recommendations on field measurements, more detailed information about the vegetation in the parks is needed, and the field measurement period should last longer.

4.2.3. Research methods

To analyze the relationship between ES supply and ES demand in three different public green spaces in Guangzhou, this study implemented a comprehensive analysis taking four ESs into account. Each service requires various measurements and valuation methods, increasing the complexity and difficulty of investigation to some extent. Moreover, ES demand depended on human senses and cognition accompanied by multiple standards and uncertainties. This study depicted the demand and evaluation standards of the interviewees from multiple perspectives as much as possible through question design thus may enhance the difficulty of understanding this study for readers. Overall, this study suggests that the research indicators and standards should be unified in the future research of ESs.

Despite the above limitations, our study provides a reference point for urban park designers and managers by quantifying ESs of the different UGIs and people's WTP, thereby contributing to the ongoing and increasing development of more human-oriented and localized urban design and planning. This study suggests that local governments should properly guide people's perception of the UGI by education and publicity of the ESs. The construction of the UGI should be comprehensively planned by combining ecological integration with social perception factors. Considering the preferences of the respondents, the entertainment value, education value, and health value of the UGI could be strengthened to meet people's perceived needs.

Declaration of Competing Interest

None.

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Appendix A. Supplementary data

Supplementary material related to this article can be found, in the online version, at doi:https://doi.org/10.1016/j.ufug.2020.126774.

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#8

30TH June 2022

Town of Gawler
PO Box 130
GAWLER SA 5118

To Whom it may concern

RE: Gawler Rural Areas Land Capability Assessment – Public Consultation

We have been residents of [redacted] since 1997 on a 5 acres block. I am a wholesale commercial rose plant grower. I initially started growing roses at [redacted] on a part time basis as a second income.

As the nursery was established, I was able to concentrate solely on growing rose plants on a full- time basis, with labour help from friends and family at certain times. I was and still am dependant on mains water, water costs at the beginning were approximately 90 cents per kilolitre but has increased over the years to $3.43 per kl. Twenty years ago, I was receiving $2.20 per plant after a three-year growth cycle and currently we are receiving $3.20 per plant only, which is the going wholesale market rate.

In recent years I have been forced to lease land with bore water in an endeavour to reduce my water bill expense. Fortunately, I was lucky to find a rare and suitable parcel of land nearby. Roses need crop rotation after every growth season to allow the soil to adequately rest as rose plants are a very high nutrient dependant crop. Therefore, the majority of available land is rested at certain times, meaning of the 7.5 acres I lease, only 2.5 acres can be cropped at any one time.

Whilst being fortunate to find a small parcel of land with bore water of which to lease, it has been less and less viable growing rose plants. The sky rocketing costs of electricity to run pumps for irrigation is another prohibitive cost and of course the lease payments, labour shortages, rising chemical and fertilizer costs. As a result of the unviability of growing rose plants on a full-time basis, I have been forced to undertake part time employment to supplement the rising growing costs.

Our wish for the future Kudla area, we believe is not unreasonable, as we would like to see development in the area. We personally wouldn't wish for smaller allotments but "Lifestyle" sized allotments of perhaps approximately 1500m2 which would in my opinion have minimal infrastructure expenses.

Kind regards

Arthur and Robyn Christou

[redacted]

#9

From [redacted]
Sent: Friday, 01 July 2022 02:58 PM
To: Jack Darzanos
Subject: Draft Gawler Rural Areas Land Capability Assessment- Public Consultation

Dear Jack Darzanos,

I wish to write to council and provide my opinion that as I reside in the area of Hillier which is being reviewed under the Draft Gawler Rural Land Capability Assessment Report that it is not viable for primary production and the review has not catered for the diversity that is required in the region. There needs to be time to engage with residence to help develop a viable alternatives for land use in the region that caters for council needs and the needs of the residence in this area.

If the opportunity presents itself, I wish to be heard at council so I can explain my views further.

Regards,

Domenic Cavallaro
[redacted]

#10

To Jack Darzanos
Acting Manager
Development Environment and Regulatory Services
Gawler Council

Dear Jack,
Thank you for the opportunity to respond to the Draft Gawler Rural Areas Land Capability Assessment Report. There are a number of things that I would like to comment on, particularly around economic viability of primary production on small acreages in the area.

In the interests of being brief I would like to state that some of the tables and information provided are quite erroneous and out of date, for example table 7-9 (almond gross margin data), ground water data (p.37), recent water quality from the Bolivar treatment plant (p.37). I would be happy to discuss them with you at a later date.

I noted that the Executive summary and the conclusions reached on pages 68-69 are largely similar to, and reinforce, what residents have previously presented to council, namely that

- properties are too small for economies of scale and are best suited to poly-house production or limited specialty crops
- there are insufficient water resources, and these are generally unaffordable for economic primary production

Having said this, it saddens me to think that council has spent valuable ratepayers' money to reinforce what they have already been told by residents. Does council really think that property owners would not have pursued alternative crops if they were profitable?

I am not a soil scientist, but through experience and observation, I would agree with the conclusions reached about soil in this report. That is, that the soils in this district are largely suited to primary production, and that they can be (at cost) amended or ameliorated to suit some crops as needed. In this regard, I would say that the report has been thorough in assessing the land capability.

I do, however, have significant reservations and a difference of opinion regarding the economic viability of small land holdings in this area. I note that the report did not adequately address fixed infrastructure costs, utility costs, owner's labour costs or the amount of area required for such things as infrastructure, headlands, property thoroughfares, housing or the need for land rotation. I do not understand why the report chose to use case studies of traditional crops grown elsewhere on the NAP area (eg. celery, onions, potatoes, carrots, lettuce, brassicas etc.) when these crops have traditionally not been grown in this area for many years, if ever. I would suggest that these crops are simply not viable because of the lack of affordable water, insufficient property size and high mechanisation costs. I felt it was also pointless using vineyard/micro wineries and citrus production in the Sunraysia as case studies for potential land use in this area. These activities, again, need considerable infrastructure, larger parcels of land and significant amounts of good quality, affordable water in order to be viable.

The report suggested a small number of people may make an income from native food crops and olive oil production. This may well be the case. More traditional crops like leafy green vegetables and herb production may be more suitable to the area and with a higher market potential but these were not referenced.

I do agree with the report that polyhouse production possibly offers the greatest potential as a viable activity on these small acreages and an area of 5ha could house 40-60 polyhouses which seems to be the norm in the Virginia area. It should be stressed that like all horticultural crops, these are not always economically viable and depend on market forces. Does the council really want this as an outcome?

I would like to draw your attention to the recommendations made on pages 68-69 and note that these conclusions reiterate what residents have been saying. Water is the primary limiting factor. Unfortunately, this report does not address this to any large degree other than that the council investigate looking at accessing water from the "Barossa New Water Project". I agree and I strongly urge that the council very closely examines the delivery parameters, quality and costs of this water. Some aspects to consider are

- Quality/Suitability
  - will this water be Class A recycled water
  - what range will the conductivity of the delivered water be
  - what will the sodium absorption ratio be
- Delivery
  - will it be delivered to the property under pressure or a guaranteed minimum daily flow rate
  - how will it be reticulated throughout the district
- Storage
  - what do individual property owners require for storage
- Costs
  - will delivery to individual properties require $2.50/kl contribution to infrastructure costs
  - will there be an availability charge
  - will the consumption charge be .49c/kl or .99c/kl (+ CPI)
  - will it be a "take and pay contract"
  - what are the anticipated grower infrastructure needs (e.g headworks, distribution pipes, power, filtration etc.)
  - what are the anticipated electricity and pumping needs for using this water
- Waste
  - if desalination is required for hydroponic purposes, how will brine be disposed of

I would speculate that the report now raises more questions than answers to the potential land use in this area. I would also like to suggest that the council speak to existing horticulturalists in the area and gain some "on the ground" information about land use, recycled water use and general economic viability in the area and not just rely on a desk top study using secondary sources. As the only commercial user of recycled water in the Gawler Council area, I am happy to show councillors the requirements need to use this resource.

Finally, I am quite happy to expand on what I have written about and address any questions council may have.

Kind regards,
Nick Pezzaniti

#11

Jack Darzanos

Gawler Council

Dear Sir,

Thank you for your letter and invitation of a submission in regard to the Gawler Rural Zone.

You are correct in noting I have had a previous interest in this area and that is because I own a commercial property within an industrial area known as the 'Northern Trade Centre'.

This area of industry is not unlike the industrial setting of Paxton street Gawler, the difference been that here we operate under the incorrect zoning. This anomaly was created by the Gawler Council some 34 years ago by removing the Industrial status that all existing industry was developed on, and rezoning 'Rural'. This has placed restraints on all business activity with little to no progress of the area in that time, greatly affecting property owners opportunity to realise their original investments where they had been guided by development plans for industry at that time.

Why has this happened? Because members of the Gawler Council decided a 'Green Belt' needed to be established to restrict all further development, for FEAR, the town of Gawler would be lost in encroaching development. Best way to do that is rezone Rural.

I have spoken at Council meetings, placed submissions over the years in an effort to have the area restored to its original zoning with no results. It seems Gawler's identity is far more important than the economics of the state.

The Arris assessment report is just another investigation not unlike 'Jenson Report' of the Kudla area compiled a few years ago, [funded by rate payers] to justify the existence of a 'green Belt' and an attempt to convince the majority of land owners that they are on primary production land.

The 'Land Capability Assessment Report' and community consultation is a required process of ticking the next box so that council can have this area locked in for another 10 years or so with a rural zoning.

Thank you again but I do not wish to waste my time anymore on fruitless submissions.

Regards

Anthony Fahey

PS

Feel free to share this at the related meeting.

Brenton Williams

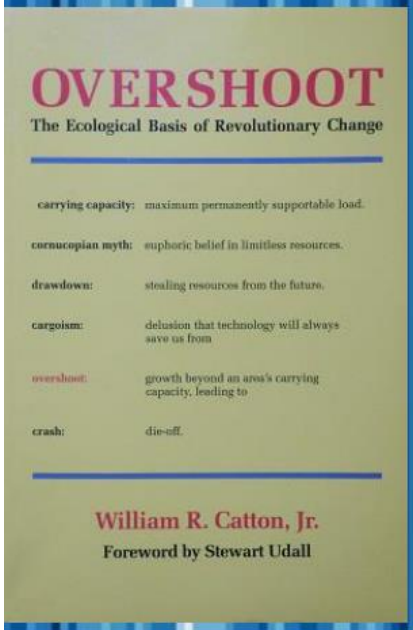
blunt commentary

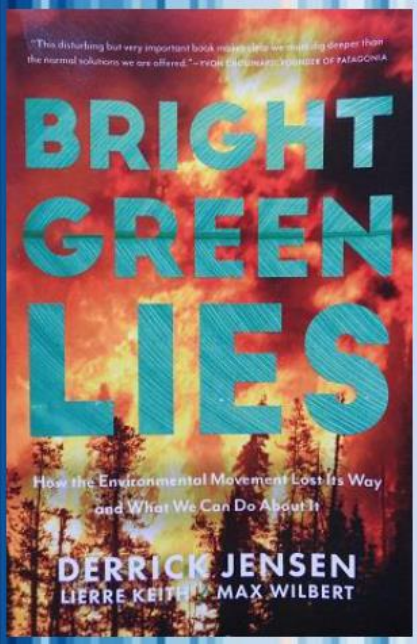
Submission in relation to:

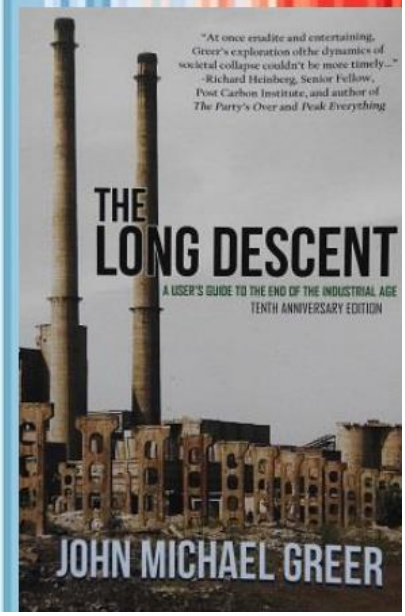
Draft Land Capability Assessment

Gawler Rural Zone

For: Town of Gawler







Introduction

I am quite bewildered as to why the Gawler Council has again seen fit to waste ratepayer funds on commissioning an investigation and report into the potential for primary production in the Rural Zone.

The matter that requires attention in relation to the Southern Rural Areas is one of appropriate zoning, and it is obvious to anyone with half a brain that the current zoning does not, and never will, reflect the reality of land use in the area, which is primarily of a rural living nature.

The Gawler Council has failed to resolve this matter over the course of several decades. It is clear to those who have taken a long-term interest in the various machinations surrounding this issue that, for some unbeknown reason, the various Elected Members have collectively been unable or unwilling to change the zoning to reflect reality.

I must admit a certain curiosity in wanting to understand the basis for this collective failure over time. It is a simple matter of incompetence? Quockerwodgery? Personal agendas? Whatever the cause, like many landowners in the Southern Rural Areas I no longer have any confidence in the ability of the Council to resolve this matter. The Town of Gawler has shown itself to be a bad faith actor in relation to this issue.

As I do not believe the Town of Gawler is genuinely interested in what landowners have to say about this latest report, I am not going to waste much time producing a comprehensive submission. I will focus on one particular aspect of the Draft Land Capability Assessment, addressing the following question: has Arris, in analysing land suitability for various types of primary production in the Southern Rural Areas, adequately and accurately assessed the factor of *climate* in their deliberations?

Climate

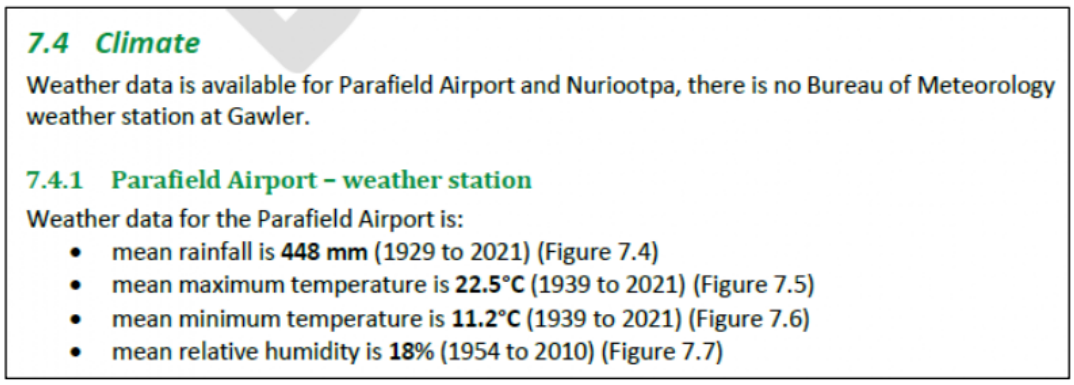
The stated aims of the Land Capability Assessment - Gawler Rural Zone, produced by Arris Pty Ltd for the Town of Gawler are to:

- Assess the capability and suitability of Rural Land within the Town of Gawler for primary production; and
- Assess the factors that impact the commercial viability of primary production within the Rural Zone.

Arris defines *land suitability* for a specific land use or crop type as an assessment of "all soil and land limitations, and other factors such as climate, infrastructure, water availability and gross margins".

One might expect that *climate* as a factor in considering land suitability would warrant an extensive treatment, given that climate systems around the world are undergoing abrupt change.

Climate as a factor in the context of land suitability is discussed in section 7.4 of the report, constituting approximately half a page of text and commencing as follows:



7.4 Climate

Weather data is available for Parafield Airport and Nuriootpa, there is no Bureau of Meteorology weather station at Gawler.

7.4.1 Parafield Airport – weather station

Weather data for the Parafield Airport is:

- mean rainfall is **448 mm** (1929 to 2021) (Figure 7.4)
- mean maximum temperature is **22.5°C** (1939 to 2021) (Figure 7.5)
- mean minimum temperature is **11.2°C** (1939 to 2021) (Figure 7.6)
- mean relative humidity is **18%** (1954 to 2010) (Figure 7.7)

Figure 1: Arris climate waffle

The first gobsmacking observation is that Arris does not appear to understand the difference between climate and weather. Various climate parameters are presented as "weather data".

Arris has presented climatological data calculated over periods ranging from 56 to 92 years. The recognised standard for calculating such data is to use a 30-year period [1].

Arris then provides a dog's breakfast characterisation of the prevailing climate for the Gawler Rural Zone:

> The Gawler Rural Zone is in the Temperate climate zone (Bureau Meteorology) with distinctly dry (warm) summers. Winter rainfall dominates with 50 mm in June, July and August. Up to 20 mm has been recorded during summer months (December to March). The mean monthly temperature during summer is 30°C during summer and the mean minimum is 7°C. Frosts are possible during winter. The mean monthly 9 am relative humidity is 50% during summer and mould and bacteria related plant diseases are possible following summer rainfall and warm conditions. Wind speeds (3 pm) are consistent throughout the year ranging from 18 km/hr in winter to 25 km/hr in summer.
> **Weather conditions are ideal for a range of crops with no extreme highs or lows, however irrigation will be required throughout the year particularly during summer (December to March).**

Figure 2: A dog's breakfast

Arris states that "Up to 20mm (of rainfall) has been recorded during summer months". What is the meaning of this sentence? Bureau of Meteorology (BOM) monthly rainfall data for the Gawler Council Depot station shows that, for example, 118mm of rain was recorded in December 2010; 53mm rain was recorded in January 1996, and 97mm rain was recorded in February 2014. Clearly there is no ~20mm upper bound in historical rainfall records for summer months in Gawler.

The report states:

> "The mean monthly temperature during summer is 30°C during summer and the mean minimum is 7°C"

FFS, isn't someone tasked with proof reading these reports before they are released to the public?

What is meant by "the mean minimum is 7°C"? The sentence begins by giving a value for the "mean monthly temperature during summer", so are we to assume the "mean minimum" is also a mean of minimum temperatures in summer months? Or some other period perhaps?

Figures 3 and 4 shows BOM monthly mean minimum temperatures at the two weather stations indicated as proximate to Gawler in the Arris report:

Summary statistics for all years

Move mouse over highest and lowest daily temperature to view dates

Statistic	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Mean	16.4	16.4	14.6	11.8	9.3	7.0	6.3	6.7	8.2	10.2	12.8	14.9

Figure 3: Monthly mean minimum temperature data, Parafield Airport station

Summary statistics for all years

Move mouse over highest and lowest daily temperature to view dates.

Statistic	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Mean	14.6	14.4	12.0	9.2	6.9	5.0	4.7	4.9	6.6	8.2	10.8	12.5

Figure 4: Monthly mean minimum temperature data, Nuriootpa station

Based on the data from the Parafield Airport and Nuriootpa stations, it is clear that the mean minimum temperature during summer months in Gawler is much higher than 7°C.

Perhaps the "mean minimum" quoted by Arrris refers to the mean minimum daily temperature?

An analysis of BOM data shows that:

- The mean daily minimum temperature at the Nuriootpa station was 9.17°C (based on daily observations covering the years 1996 to 2022, the period for which data is available).
- The mean daily minimum temperature at the Parafield Airport station was 11.18°C (based on daily observations covering the period 1990 to 2020).

Unless the Gawler Rural Zone happens to occupy some anomalous climate cold zone on the northern Adelaide Plains, it is clear that the mean minimum daily temperature is higher than 7°C.

It is not at all clear what Arris means by "the mean minimum is 7°C" in their sloppily constructed sentence. The hodgepodge of factoids in Figure 2 does not provide an intelligible description of the climate for the Gawler Rural Zone.

Arris claims, (in bold text), that "weather conditions are ideal for a range of crops with no extreme highs or lows".

The BOM defines a "very hot" day as one for which the maximum temperature exceeds 40°C [2].

Using the Parafield Airport and Nuriootpa weather stations as proxies for Gawler, Figures 5 and 6 show that very hot days have occurred in every year over the past two decades.

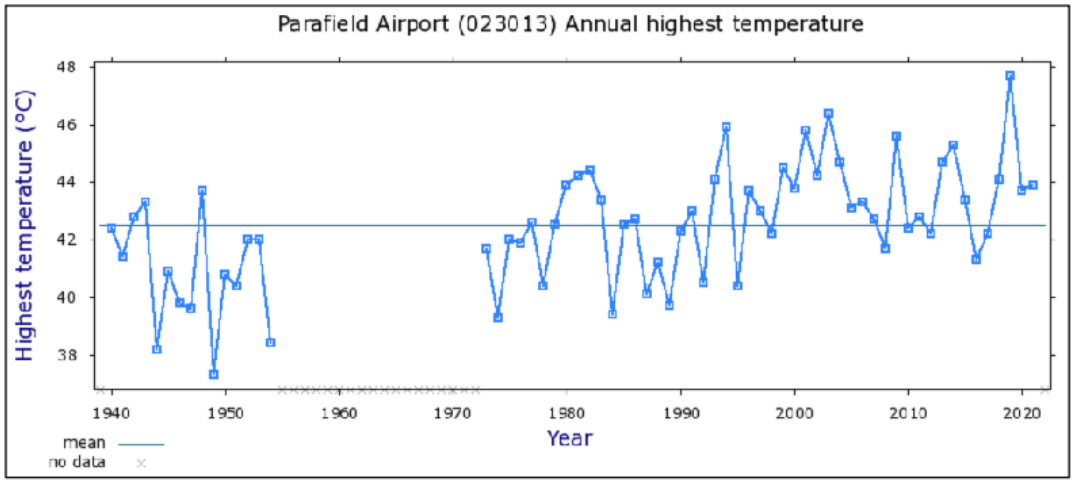


Figure 5: Annual highest temperatures recorded at the Parafield Airport station

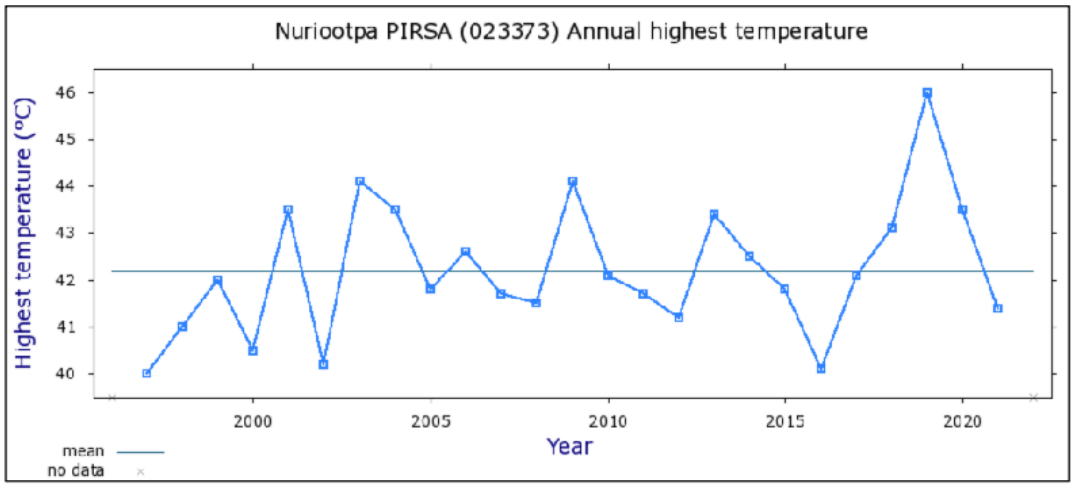


Figure 6: Annual highest temperatures recorded at the Nuriootpa station

The BOM defines "hot days" as those with maximum temperatures exceeding 35°C, and "very hot" days as those with maximum temperatures exceeding 40°C. Although the BOM does not define what might be considered an "extremely hot" day, it would seem reasonable to define it as one for which the maximum temperature exceeds 45°C. On this basis, data from the Parafield Airport weather station shows there have been 7 days since 2000 which can be classified as extremely hot days.

Arris's claim that weather conditions in the area exhibit "no extreme highs" is demonstrably false.

Climate Change

Climate change is recognised as posing a serious threat to food production systems in Australia. According to the Australian Academy of Science [3]:

- "Australian agriculture, forestry, fisheries and food systems are being negatively impacted by climate change, with serious risks unfolding over the coming decades"
- "Yields of fruit and vegetable crops are likely to be reduced due to decreases in irrigation water availability and increases in temperature that reduce both quality and quantity of produce"
- "Viticulture and horticulture may be affected by increasingly late frosts that interact with earlier budburst and flowering due to higher average temperatures, substantially increasing the damage to grape, fruit and cereal crops"

Despite the fact that climate change arguably represents the most significant risk to the future viability of primary production enterprises in Australia, it is not mentioned even once in the Arris report. If climate is a factor which must be considered in assessing land suitability for primary production enterprises, and the climate is abruptly changing, then obviously an analysis must be undertaken to assess potential impacts of future likely climate scenarios.

It is not as if there is a dearth of information available to inform such an analysis, for example:

- Horticulture Innovation Australia Limited, in conjunction with the South Australian Research and Development Institute, published a detailed analysis in 2019 titled "Managing almond production in a variable and changing climate" [4], seeking to "identify and rank risks to almond production that can be expected due to climate change". Specific information is provided for the northern Adelaide plains region.
- Fraga et al [5], in reviewing future impacts of climate change on Mediterranean olive orchards, find that: "recent studies applied to olive trees have shown that this crop can be strongly affected by climate change, particularly under the Mediterranean type-climates"
- Venios et al [6], in assessing grapevine responses to heat stress and global warming, state that: "The grapevine (Vitis spp.) is quite sensitive to extreme temperatures", and "Many viticultural zones, particularly in Mediterranean climate regions, may not be suitable for growing wine grapes in the near future unless we develop heat-stress-adapted genotypes or identify and exploit stress-tolerant germplasm"
- Srikanth et al [7], in reviewing the impact of climate change on capsicum production, state: "Climate change will effect capsicum production through increase in pollination failures, floral abortion, reduced fruit size and quality under higher temperature, increased incidence of physiological disorders (sun scald and blossom end rot), increased risk of soil borne diseases (leaf blight and fruit rot)"

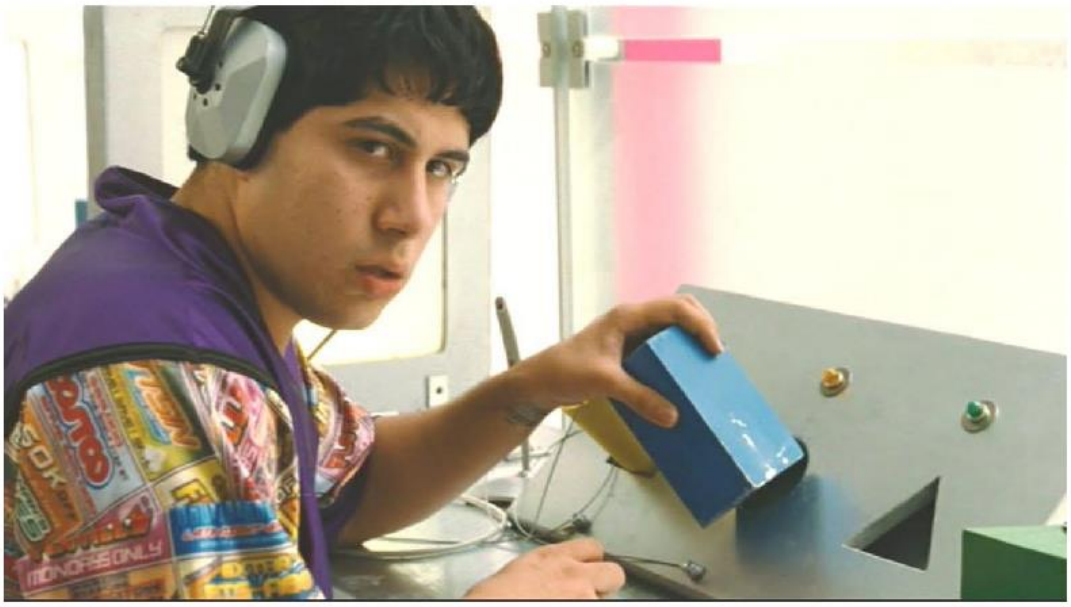
As can be seen, the horticultural industry and academia are well aware of the serious risks posed by climate change to the viability of production of several of the crop types discussed in the Arris report. For Arris not to have addressed this critical factor is inexcusable.

Summary

The authors of the Land Capability Assessment report produced by Arris Pty Ltd:

1. Do not appear to understand the difference between weather and climate.
2. Have not used standard 30-year periods for calculation of climate parameters.
3. Have provided a discombobulating description of the climate of the Gawler Rural Zone.
4. Have provided erroneous information, claiming that extreme maximum temperatures do not occur in the Gawler Rural Zone.
5. Fail to even mention climate change in the report – hence one would assume are completely oblivious to the serious risks posed to the viability of primary production enterprises by abrupt irreversible global heating.

Based on these observations, I can only conclude that the authors of the report lack the necessary knowledge and competence required to conduct an assessment of land suitability that incorporates a consideration of climactic factors.



Conclusion

The Land Capability Assessment report was commissioned to assist in answering the following questions:

- What is the land capable and suitable for growing across the Rural Zone?
- What factors impact on the commercial viability of primary production in the Rural Zone?

The report cannot hope to answer the first question, as it purports to assesses land suitability based on a largely unintelligible description of a climate that no longer exists.

The report does not even mention climate change, which, in conjunction with the implications of peak oil, are the most significant factors likely to impact the commercial viability of primary production in the Rural Zone in the decades ahead. David Attenborough recently stated to the United Nations Security Council: "if we continue on our current path, we will face the collapse of everything that gives us our security: food production, access to fresh water, habitable ambient temperature and ocean food chains" [8]. For Arris not to have even mentioned climate change suggests the report should immediately be consigned to the dustbin.

Why has the Gawler Council wasted ratepayer funds on yet another half-arsed investigation and report? Why does the Council engage external consultants to hypothesise about the commercial viability of growing quandongs in the Rural Zone, when instead it could simply consult with long-standing landowners who have first-hand experience and years of records in relation to what is profitable (or not) to grow in the area?

Having followed the debate on this this issue for nearly 20 years, I have come to the conclusion that Gawler Council is either incapable of, or actually has no interest in resolving the long-standing festering issues relating to zoning and land use in the Southern Rural Areas. At all levels of government, a standard tactic for kicking the can down the road is to insist further investigations and "expert" reports are required. I suspect that some longstanding Elected Members of the Council actually prefer to keep this issue unresolved and maintain division within the community in order to promote anti-development credentials within their small-world constituency in Gawler, while concurrently presiding over the destruction of the character of the Gawler township via indiscriminate subdivision and hideous urban sprawl developments.

Given that the Elected Members of the Gawler Council have, over the course of the past four local government election cycles, collectively shown themselves to be either incapable or unwilling to fix the inappropriate zoning classification for the Southern Rural Areas, I suggest the matter now be resolved at the State Government level. This is especially warranted due to the fact that the Council has seen fit to commission yet another unnecessary investigation timed to coincide with the closing months of the term of the incumbent Elected Members, leaving no scope for progress on the matter to be made ahead of caretaker provisions coming into effect in September prior to local government elections in November. While some may hope the upcoming local government election delivers a Council that acknowledges the zoning for the Southern Rural Areas is ridiculous, the likely continued presence of councillors who have, for whatever reason, demonstrably shown themselves to be an impediment to addressing this issue, will mitigate against a resolution of the matter.

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