Ecosystem Services and Economic Assessment of Land Uses in Urban and Periurban Areas

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Abstract

This work quantified ecosystem services (ES) and the geographic gross product (GGP) at municipal level in the Metropolitan Region of Buenos Aires (MRBA), Argentina. The ES offer and GGP were evaluated for each land use (extensive agriculture EA, intensive agriculture IA, urban and periurban agriculture UPA, green areas GA, urban use URB), expressed as a percentage (%), at the municipality level. Municipalities with a greater URB percentage (<70) presented an elevated ES offer from GA. In periurban municipalities EA contributed to ES offer more than other vegetated land uses (IA, GA, and UPA). Urban municipalities presented 20% more GGP than periurban municipalities. The GGP was negatively associated with total ES offer (−0.34) and ES offer from EA (−0.46). The identification and quantification of ES and GGP is relevant for achieving an adequate landscape planning and a sustainable environmental and economic use of urban systems.

Keywords Megacities · Metropolitan Region of Buenos Aires (MRBA) · Vegetated uses · Geographic gross product (GGP) · Sustainable urban environments

Introduction

Urban landscapes exhibit different spatial and temporal patterns, both related to uses diversity (for example: urban settlements, empty spaces, forested areas, urban reserves, productive areas, and among others). Human activities changes landscape structure increasing its fragmentation. The latter occurs in large areas worldwide, and affects the availability of goods and ecosystem services (ES) associated with urban and periurban environments (Costanza et al. 1998; Kremen et al. 2007) (Szumacher and Malinowska 2013). Urban and periurban ecosystems are a consequence of the anthropic creation and ruled by human societies. Also, human regulation affects, positively or negatively, urban ES and may affect inhabitants life quality in the cities (Morello 2000; Szumacher and Malinowska 2013 Endreny 2018).

The environmental and social benefits of urban ES are related to landscapes which include green areas (GA) and urban or periurban agriculture. The latter have been documented by several authors, which indicated that these landscape uses are essential to maintain the sustainability of urban and periurban ES (Pérez-Vázquez and Leyva-Trinidad 2015; Szumacher and Malinowska 2013; Endreny 2018). The Food and Agriculture Organization (FAO 2016) recorded how urban forests help to sustain nine United Nations Sustainable Development Goals (SDG): zero hunger, zero poverty, well-being and health, uncontaminated water and sanitation, cheap and clean energy, descent labor and economic growth, climate achievement, land living, sustainable cities, and communities (Endreny 2018; Peng et al. 2017). Likewise, the conservation of vegetated uses, such as GA and urban or periurban agriculture, in the cities fulfils water and food provision, climate regulation, among other fundamental ES for urban population. Therefore, in urban environments, population life quality, is highly related to ES offer and the virtuous environmental–social link they can maintain (Endreny 2018; Szumacher and Malinowska 2013; Zezza and Tasciotti 2010).The set of interactions between the environmental domain, where ES are generated, and the social domain, where ES are used, have a positive influence on human welfare and economic variables. Since, socioeconomic variables, such as the geographic gross product (GGP), could be affected by ES offer from vegetated urban uses (Szumacher and Malinowska 2013; Peng et al. 2017).

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Therefore, economic variables analysis, and its relationships with ES offer, could contribute to a better understanding between environmental and economic dynamics in the permanent evolution of urban landscapes (Vila Subirós et al. 2006; Szumacher and Malinowska 2013).

The GGP, in megacities worldwide, as in the Metropolitan Region of Buenos Aires (MRBA), presents a wide variety of productive activities and land uses which contribute to its increase. The latter reveals the economic activities heterogeneity that take place in megacities and in MRBA (Civeira 2016; Lodola et al. 2013; Peng et al. 2017). Although, some studies have observed an underlying relationship between urbanization, socioeconomic variables (such as GGP) and ES, some features are still uncertain. A recent research made in periurban area of Beijing city, which quantified total ES response to construction land proportion, urbanization, population density, and GGP concluded that total ES diminished quickly with intensifying urbanization level (Peng et al. 2017). Likewise, many studies summarized research needs in environmental and economic indicators, at different spatial and temporal scales, in order to understand urban uses and its role in ES provision, (FAO 2016; Samson 2017; Szumacher and Malinowska 2013; Vila Subirós et al. 2006). The environmental unknowns comprise: vegetation characteristics which increase ES provision, urban vegetation, and human well-being connection and how these could link to social and economic improvement (among others: GPP increase) (Peng et al. 2017; Samson 2017; Szumacher and Malinowska 2013).

MRBA landscapes, as in other world megacities, are facing environmental, social and economic crisis (Morello 2000; Endreny 2018, Szumacher and Malinowska 2013). For instance, urban and periurban landscapes are being degraded and fragmented, due to land construction expansion over vegetated areas (Morello 2000). Meanwhile periurban vegetated areas decreased, it has been recorded, by several researches, the decoupling of ES relations between cities and country areas (Endreny 2018, Szumacher and Malinowska 2013). The latter occurred, due to local and global processes, such as land use changes toward more constructed areas (urbanized). Consequently, in urban and periurban areas, ES provided by vegetated uses (e.g., GA, urban and periurban agriculture) are rapidly decreasing (Endreny 2018, Szumacher and Malinowska 2013). It has been verified that urbanization advance on agricultural and seminatural landscape uses, affected negatively land capability, and ES provided by soils. Moreover, in urban areas worldwide, land capability degradation generated losses of different ES such as: nutrient cycling, erosion control, biomass production, CO_2 control, and detoxification (Civeira 2016; Szumacher and Malinowska 2013; Rivas 2010; Endreny 2018).

A suitable landscape planning in the MRBA, and megacities worldwide, needs to maximize environmental and economic sustainability. The latter, could be achieved including mixed landscapes with patches of native vegetation, agriculture, afforestation, and urbanized zones equally combined (Civeira 2016; Endreny 2018; Szumacher and Malinowska 2013). From the previous stated, it is necessary to recognize and understand urban and periurban reaction to different landscape uses, including the ecosystems dynamics, ES provision, and its effect on economic variables (e.g., GGP). The latter seems highly necessary, since today many anthropic activities are generating urban ES degradation and economic variables decline in megacities worldwide. Consequently this research objective included: the quantification of ES and GGP in urban and periurban municipalities, with different land uses proportion, at MRBA in Argentina.

Materials and Methods

Description of the Study Area

The studied area covers a wide range of districts (municipalities) which are detailed in Table 1. This area covers ~18,000 km² of surface and includes municipalities from Buenos Aires province, plus the Autonomous City of Buenos Aires (CABA). Approximately, 15 million people lives in this territory and the population density is 736 inhabitants km² (INTA 2012). The MRBA spatial components present a radial and circular distribution (Fig. 1). This spatial distribution allowed the differentiation between two levels of urbanization: urban and periurban areas. Also, these levels of urbanization presented dissimilar ecological and socioeconomic characteristics (Civeira 2016; INTA 2012; Vidal-Koppmann 2014) (Table 1). The MRBA presents a remarkable heterogeneity of vegetated and urbanized land uses, since this territory was ordered from different economic, social and environmental public policies and rationalities (Fig. 1) (Vidal-Koppmann 2014). Land uses surveyed for this research were: extensive agriculture (EA), which included grain productions and implanted pastures; intensive agriculture (IA) including horticulture, floriculture, and farm activities; urban and periurban agriculture for self-consumption and eventual surplus commercialization (UPA); GA; urban use (URB) and other unspecified uses (Ot). All land uses from the MRBA were expressed as a percentage (%) at the municipality level. The information was compiled from different data sources: Provincial Office of Urban and Territorial Organization, Buenos Aires Atlas, Metropolitan Observatory and Agricultural census (more data in Civeira 2016).

Table 1 Municipalities included in the metropolitan region of buenos aires (MRBA) and urbanization level (urban and periurban)

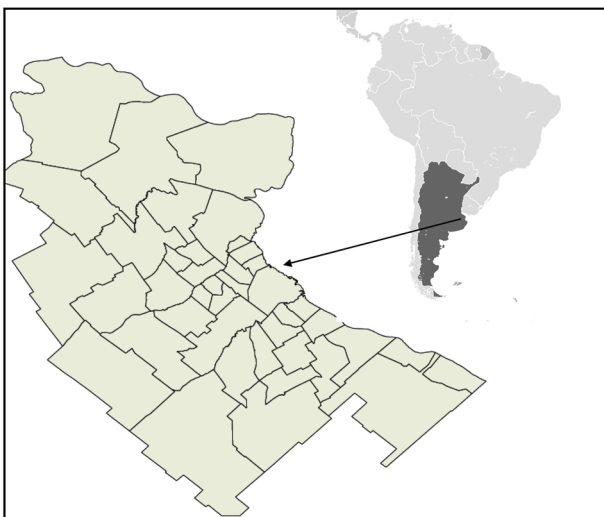| Urbanization level	Municipality		Urbanization level
Periurban	Almirante Brown	Avellaneda	Urban
Periurban	Berazategui	CABA	Urban
Periurban	Berisso	Esteban Echeverría	Urban
Periurban	Brandsen	General San Martín	Urban
Periurban	Campana	Hurlingham	Urban
Periurban	Cañuelas	Ituzaingó	Urban
Periurban	Ensenada	José C. Paz	Urban
Periurban	Escobar	La Matanza	Urban
Periurban	Exaltación de la Cruz	Lanús	Urban
Periurban	Ezeiza	Lomas de Zamora	Urban
Periurban	Florencio Varela	Malvinas Argentinas	Urban
Periurban	General Las Heras	Merlo	Urban
Periurban	General Rodríguez	Moreno	Urban
Periurban	La Plata	Morón	Urban
Periurban	Lobos	Quilmes	Urban
Periurban	Luján	San Fernando	Urban
Periurban	Marcos Paz	San Isidro	Urban
Periurban	Mercedes	San Miguel	Urban
Periurban	Pilar	Tigre	Urban
Periurban	Presidente Perón	Tres de Febrero	Urban
Periurban	San Nicolás	Vicente López	Urban
Periurban	San Pedro		
Periurban	San Vicente		
Periurban	Zárate		

Fig. 1 Location of the studied area: Metropolitan Region of Buenos Aires (MRBA), Argentina

Valuation of Ecosystem Services and Geographic Gross Product

ES offer for each land use at the municipality level were quantified using an adapted version of the relative estimation equation, which presented a range between 0 and 100 (Barral and Maceira 2011; Viglizzo et al. 2004) Eq. (1). The ES offer estimation equation included: (1) soil protection services (Sprotec), which contains erosion prevention and sedimentation of watercourses and landslides; (2) water purification and supply services (e.g., biomass effect on rainwater retention and infiltration) (Sppwater), and (3) provision and habitat services, which favors biodiversity conservation (Shab). The above description is summarized in the following equation:

$$\begin{aligned} \text{SE offer} = &(\text{Sprotec}) \times 0.1667 \times 1.50 + (\text{Sppwater}) \\ &\times 0.1667 \times 1.75 + (\text{Shab}) \times 0.1667 \times 2.0, \end{aligned}$$
(1)

coefficients used in Eq. (1) represented an internal compensation in order to balance the equation. The latter provide equal factors weight and avoid exceeding the value of 100 in the total sum of ES offer. Likewise, the coefficients 1.50, 1.75, and 2.00 are compensation numbers and avoid numerical degradation of each equation factor. Equation (1) increases its level of degradation within the 0–100 scale when more components integrate a factor and loses their relative weight. Therefore, the relative weight of

Table 2 Geographic gross product (GGP) items and equations (adapted from statistics and censuses made by buenos aires province government and Lódola et al. 2013)

Geographic gross products (GGP) sectors and items	Municipality GGP equation (%)
Services production sector	
Commerce	
Financial intermediation	
Services of the public administration, defense, and compulsory social security	
Teaching and health services	$\frac{\text{services production sector} \times 100}{\text{Sum (services production sector} + \text{goods production sector)}}$
Social, association, and personal services	
Private household services (domestic service)	
Hotels and restaurants	
Transportation, storage and communications services	
Real estate, business, and rental services	
Goods production sector	
Agriculture, livestock, hunting and forestry, fishing	$\frac{\text{goods production sector} \times 100}{\text{Sum (services production sector} + \text{goods production sector)}}$
Manufacturing industry	
Building	
Exploitation of mines and quarries	
Electricity, gas, and water	

these factors needs to be balanced, so each one was multiplied by a coefficient based on the number of multiplicative factors which constructed the Eq. (1) (Barral and Maceira 2011; Viglizzo et al. 2004). Since ES offer were not calculated in relation to water bodies, parameters related to them were multiplied by 0, in order to be accounted as equal for all land uses types.

In Eq. (1), ES offer were calculated from net aerial primary productivity (NAPP Mg ha^{-1} year^{-1}). NAPP was obtained through yields and the amount of hectares occupied by vegetation (e.g., grain crops, vegetables, and ornamental plants) for the different land uses (EA, EI, UPA, and GA) at the municipality level. The methodology used in this research followed one proposed by Prince et al. (2001). In our research, ES offer, provided by NAPP, was estimated at the municipality level: as the sum of vegetation types included in each land use (EA, IA, UPA, and GA) and the total ES offer was calculated as the sum of all land uses, according to Eq. (1). Each of the parameters, in Eq. (1), was calculated from average data of vegetated spaces in the municipalities of MRBA, within the period 2002–2012. More details about this methodology could be obtained in published researches made by Muschietti and Civeira (2017) and Civeira (2016).

To evaluate the gross domestic product (GDP) at the municipal level, as suggested by the bibliography, the corresponding category is the GGP (Geographical Gross Product) which, unlike its counterpart at the national level, assigns to the GDP value a spatial criterion (Peng et al. 2017; Lódola et al. 2013). Therefore, GGP was the variable selected to analyze each production sector (production activity) at the municipality level (Lódola et al. 2013). As

explained in the bibliography, GGP is the sum of goods and services produced in a certain geographic jurisdiction (in our research: municipality and MRBA) over the course of a year and is calculated as the sum of each economic sector aggregated value (DPE 2016, Lódola et al. 2013). So, in the present research, GGP was calculated as the sum of goods (GGP goods), services (GGP services) and the sum of them (total GGP) in each municipality (geographic jurisdiction) over the course of year 2003, since this was the last year in which available information was released. GGP was expressed in argentine national currency (pesos) and was constructed through the compilation of different censuses (industrial, economic, agricultural, and other surveys) from different sources (National Institute of Statistics and Census: INDEC; Statistics Direction: DPE from Buenos Aires and the Statistics and Census Direction from the autonomous city of Buenos Aires: EC-CABA). Using the original existing data, GGP was calculated, at the municipality level, as a percentage (%) in order to facilitate equal comparisons between MRBA municipalities (Table 2).

In order to identify statistical differences between the ES offer and the GGP at the municipalities and urbanization level, the Kruskal–Wallis test was used (by William Kruskal and W. Allen Wallis, Infostat 2016). This test is a nonparametric method and determines if the data comes from the same population. Intuitively, the Kruskal–Wallis test is identical to the ANOVA with the data replaced by categories. Also, Kruskal–Wallis test is an extension of the Mann–Whitney U test for three or more groups. Because it is a nonparametric test, the Kruskal–Wallis test assumes no normality in the data and does not require the assumption of equal variances (homogeneity of variances, as opposed to

the traditional ANOVA.) In this test, it is assumed, under the null hypothesis, that the data come from the same distribution and therefore the populations are identical. The statistical analysis included an evaluation of the correlations between the ES offer and the GGP. For this correlation, the effect of the GGP and ES offer at each municipality was analyzed and the corresponding correlations were made by means of the statistical regression called Pearson correlation (Infostat 2015).

A principal component analysis (PCA) was performed using the same information described above. PCA was performed to identify variables (land uses percentage: EA, IA, GA, UPA; URB; total GGP and total ES offer), which could differentiate between municipalities according to their inherent characteristics. PCA analyzes the interdependence of the variables and finds an optimal graphical representation of the variability in the data. This analysis builds a new set of uncorrelated variables named principal components (PC), which explains the structure of the variation of the data with the least possible loss of information. The total variability explained by each PC is referred to as eigenvalues. The eigenvector (EV) is the weighted coefficient of each original variable which forms each PC. The latter shows the incidence of the original variables in defining the axes of each PC.

Results

Land uses percentages showed differences between MRBA municipalities: all vegetated uses presented <10% in urban municipalities (Table 3). These vegetated uses included EA, IA, UPA, and GA. Conversely, these municipalities presented the highest percentages in URB, reaching close to 90% in the municipality of Lanús and in CABA. Municipalities that presented lower percentages in EA were: Avellaneda, Lomas de Zamora, San Isidro, CABA, Lanús, General San Martin, Hurlingham, Vicente Lopez, Quilmes, Tres de Febrero, Morón, San Fernando, Ituzaingó, Tigre, and Malvinas Argentinas. EA use presented higher percentages (>60%) in municipalities farthest from CABA such as: Mercedes, San Nicolás, Presidente Perón, Cañuelas, Luján, La Plata, Exaltacion de la Cruz, Marcos Paz, San Vicente, Las Heras, and Brandsen General (Table 3). These municipalities presented URB percentages that varied between 4 and 17% for Brandsen and San Nicolás, respectively. Periurban area presented higher percentages of EA use (>60%) and higher percentage variations among URB use (4–15%). But it was recorded that URB use did not exceed 15% in periurban areas.

All municipalities presented UPA and the higher percentages were observed at greater distances from CABA. Also, UPA was distributed randomly in the MRBA

presenting the following order: Berisso > Quilmes > MarcosPaz > Lobos > Mercedes > SanPedro > Malvinas Argentinas > Tres de Febrero > San Nicolás > Tigre > Presidente Perón > Ensenada. Following a similar trend as the UPA, GA use was located in all municipalities (Table 3). Also in the studied region, GA presented lowest percentages and highest variability than other land uses. So, GA presented a dissimilar trend in their spatial distribution, showing percentages ranging from 2 to 35% in the MRBA. Municipalities with higher GA percentages in decreasing order were Berazategui > Berisso > Campana > VicenteLópez > Ensenada > EstebanEcheverría > Pilar > Ezeiza > San Isidro > Escobar > Moreno.

ES offer at the municipality level for each land use is shown in Table 4. Lanús, Gral. San Martín, and Hurlingham presented superior percentages of URB, minor percentages of agricultural uses (EA and IA) and as a consequence, these municipalities, presented minor ES offer (Table 4a). On the other hand, Berisso, Brandsen, San Vicente, and Zarate presented higher percentages of agricultural uses (EA and IA) and as a consequence the highest ES offers (>4). The ES offer in the urban area was lower than the periurban area (Tables 4a and 4b). Also, higher percentages of ES offer provided by IA were recorded in the periurban area. However, in municipalities with a greater URB percentage, such as CABA, Vicente Lopez, San Isidro, San Miguel, Lomas de Zamora and Tres de Febrero (<70) an elevated ES offer from the GA was also observed (Table 4).

The GGP from each municipality and urbanization level is shown in Fig. 2. Urban and periurban areas presented differences in GGP: urban municipalities presented 20% more GGP from services than periurban municipalities. As expected, GGP presented significantly relationships with GGP from services and GGP from goods ($R^2 = 0.81$, $p > 0.0012$ and $R^2 = 0.92$, $p > 0.0015$; respectively). Differences in GGP from services and goods were observed between urban and periurban areas. Agricultural uses (EA, IA) contribution to GGP were greater in periurban municipalities. On the other hand, industrial and services contribution to GGP were greater in urban municipalities. Furthermore, GGP from services highly contributed to GGP accounts especially in extremely urbanized areas (for example CABA; Table 2; Fig. 2) were businesses corporation's headquarters are settled and linked to commercial activities, services, and the most important local and international markets (Peng et al. 2017). For the whole MRBA, EA and IA were the main uses (or goods production) that contributed to GGP (Fig. 2).

Total GGP and total ES offer calculated for each municipality are presented in Fig. 3. Each municipality showed different tendencies between total GGP and total ES offer. In general, municipalities with elevated total ES offer presented intermediate or minor total GGP. On the other hand,

Table 3 Land uses: (a) urban area; (b) periurban area

Municipality	Land use type					
	EA	IA	UAP	GA	URB	Ot
(a) Urban area						
Avellaneda	0.0	0.1	0.0	12.0	80.0	6.7
CABA	0.0	0.0	0.0	3.1	96.0	0.8
Esteban Echeverría	21.0	9.8	0.1	19.5	46.0	3.1
General San Martín	1.0	5.0	0.1	6.7	79.0	7.0
Hurlingham	1.0	5.0	0.1	9.0	75.0	8.4
Ituzaingó	6.9	6.0	0.0	5.8	71.1	8.7
José C. Paz	10.0	14.0	0.1	10.0	65.0	0.8
La Matanza	35.0	7.8	0.1	5.5	44.0	6.4
Lanús	0.0	2.0	0.1	2.9	85.0	8.5
Lomas de Zamora	0.0	3.0	0.0	6.4	81.0	8.2
Malvinas Argentinas	9.0	10.0	0.5	6.0	65.0	8.1
Merlo	22.5	11.0	0.0	11.0	41.0	12.3
Moreno	20.0	9.0	0.0	14.0	45.0	10.2
Morón	6.0	9.0	0.0	8.0	68.0	7.7
Quilmes	2.0	8.0	0.9	9.9	72.0	6.2
San Fernando	6.0	15.0	0.0	10.0	66.0	2.6
San Isidro	0.0	2.0	0.1	15.0	75.0	6.8
San Miguel	11.0	14.0	0.1	9.9	62.8	1.9
Tigre	7.0	9.0	0.4	9.0	65.0	8.2
Tres de Febrero	4.0	9.0	0.4	6.0	68.6	10.2
Vicente López	1.0	3.0	0.0	25.0	68.0	2.5
(b) Periurban area						
Almirante Brown	20.0	8.4	0.0	7.7	55.0	7.6
Berazategui	26.9	9.6	0.2	35.0	20.0	7.1
Berisso	46.9	10.0	1.1	31.0	9.2	1.5
Brandsen	82.0	7.0	0.1	4.0	3.2	3.1
Campana	40.0	13.3	0.0	28.0	16.0	2.3
Cañuelas	70.0	8.0	0.1	8.0	10.0	3.3
Ensenada	59.2	7.7	0.3	19.9	11.0	1.6
Escobar	58.0	6.7	0.0	14.3	20.0	0.9
Exaltación de la Cruz	72.5	12.1	0.0	4.9	7.1	2.9
Ezeiza	56.1	4.6	0.1	15.0	18.0	5.3
Florencio Varela	43.9	18.0	0.2	4.0	29.0	4.2
General Las Heras	77.0	10.0	0.2	5.8	5.0	1.7
General Rodríguez	57.2	19.5	0.3	9.2	11.0	2.4
La Plata	68.0	5.5	0.2	11.0	12.3	2.5
Lobos	56.2	19.0	0.8	5.0	15.0	3.4
Luján	70.0	14.3	0.0	2.5	11.2	1.7
Marcos Paz	75.0	4.9	0.8	4.2	10.0	4.3
Mercedes	60.0	14.0	0.7	9.0	8.0	7.1
Pilar	48.6	11.0	0.0	19.0	11.3	8.6
Presidente Perón	63.5	10.0	0.4	9.0	15.0	1.8
San Nicolás	62.7	9.9	0.4	8.0	17.0	1.7
San Pedro	47.4	20.0	0.6	9.0	21.0	1.7
San Vicente	76.0	8.0	0.2	4.4	8.4	2.6
Zárate	42.0	15.0	0.0	12.1	20.0	9.3

(*EA* extensive agriculture, *IA* intensive agriculture, *UPA* urban and periurban agriculture, *GA* green areas, *URB* urban use, O*t* other) percentage proportion in each municipality of the Metropolitan Region of Buenos Aires (*MRBA*)

municipalities with minor total ES offer presented intermediate and higher total GGP. Also, total GGP was negatively associated with the total ES offer ($R^2 = -0.34$; $p < 0.05$) and the ES offer from EA ($R^2 = -0.46$; $p < 0.05$).

However, total ES offer was higher in a small number of urban municipalities, such as CABA and Vicente Lopez, due to a superior contribution of UPA and GA uses (Table 3; Fig. 3). Also, the presence of UPA and GA increased

Table 4 Ecosystem services (ES) offer according to land usesat each municipality in the studied region: (a) urban area; (b) periurban area

Municipality	GA	EA	IA	UA-P
Land use type				
(a) Urban area				
Avellaneda	1.30	0.09	8.97	5.97
CABA	6.76	0.00	0.00	0.91
Esteban Echeverría	4.15	0.43	6.97	0.11
General San Martín	1.71	0.09	1.49	0.06
Hurlingham	0.79	0.02	1.88	0.07
Ituzaingó	1.25	0.08	2.38	0.01
José C. Paz	2.36	0.32	3.43	0.02
La Matanza	1.94	1.27	6.27	0.13
Lanús	2.52	0.03	1.13	0.11
Lomas de Zamora	3.40	0.08	1.51	0.01
Malvinas Argentinas	1.95	2.64	3.62	0.34
Merlo	1.39	0.15	5.89	0.04
Moreno	0.39	0.03	6.92	0.03
Morón	0.59	0.03	3.69	0.00
Quilmes	1.31	0.07	8.12	1.71
San Fernando	4.00	0.38	4.64	0.03
San Isidro	3.80	0.04	1.38	0.07
San Miguel	3.46	0.21	2.35	0.02
Tigre	1.14	0.06	4.45	0.39
Tres de Febrero	2.35	0.14	3.78	0.33
Vicente López	4.21	0.04	1.28	0.02
Total urban	2.42	0.30	3.82	0.49
(b) Periurban area				
Almirante Brown	2.59	0.39	8.36	0.06
Berazategui	3.98	0.69	8.89	0.28
Berisso	3.11	0.49	9.40	2.08
Brandsen	3.45	3.04	12.14	0.44
Campana	3.53	2.98	7.31	0.00
Cañuelas	3.73	3.47	4.98	0.13
Ensenada	3.85	0.70	8.99	0.64
Escobar	3.73	0.61	8.91	0.08
Exaltación de la Cruz	4.16	3.36	5.77	0.00
Ezeiza	2.82	0.85	4.74	0.11
Florencio Varela	2.70	0.61	8.65	0.20
General Las Heras	3.84	3.14	4.13	0.17
General Rodríguez	3.37	2.82	4.09	0.11
La Plata	2.75	1.38	8.22	0.62
Lobos	3.26	3.24	4.19	0.33
Luján	2.62	2.98	6.71	0.01
Marcos Paz	1.89	3.08	3.60	1.12
Mercedes	2.87	3.41	6.15	0.59
Pilar	2.43	2.90	5.70	0.03
Presidente Perón	0.96	0.19	4.36	0.30
San Nicolás	2.89	3.39	6.99	0.55
San Pedro	3.14	4.31	5.61	0.33
San Vicente	2.45	2.88	9.67	0.49
Zárate	3.44	2.97	8.03	0.03
Total periurban	3.07	2.24	6.90	0.36

EA extensive agriculture, *IA* intensive agriculture, *UPA* urban and periurban agriculture, *GA* Green areas, *URB* urban use

total ES offer in areas with elevated urban density, as well as intensive and extensive agriculture uses (EA and IA) did in periurban areas (Table 3 and Fig. 3). Moreover, as registered by other authors (Peng et al. 2017), it was
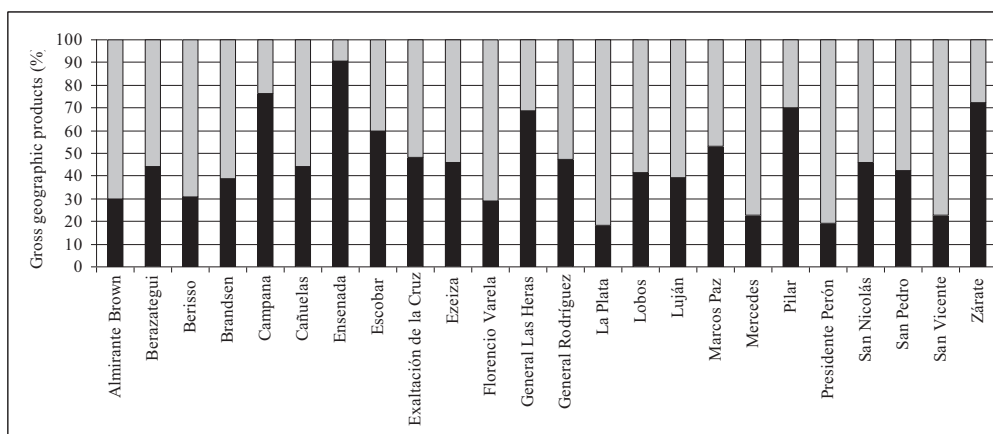
a) Urban area
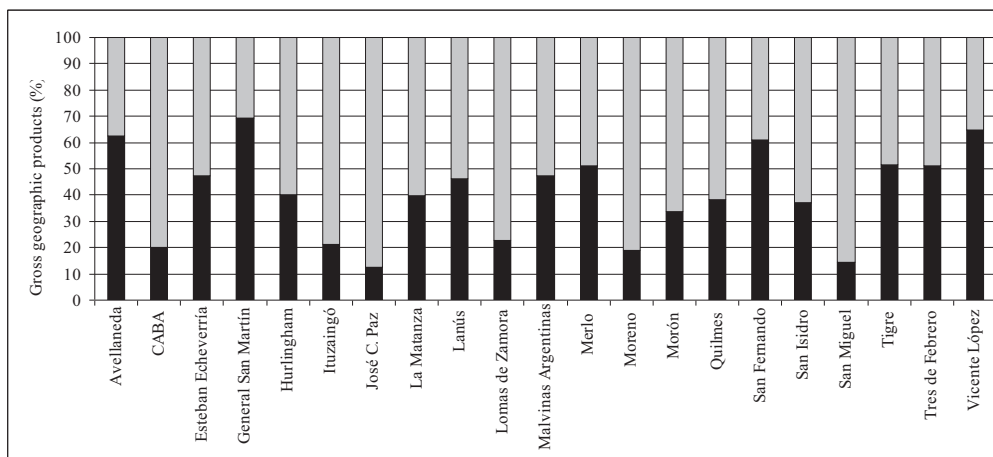
b) Periurban area

Fig. 2 Gross geographic products (GGP) in Metropolitan Region of Buenos Aires (MRBA): GGP from goods production (black bars) and GGP from services production (gray bars): **a** urban area; **b** periurban area

observed that urban use (URB) affected negatively total ES and positively total GGP (Figs. 3, 4).

The PCA allowed the analysis of the interdependence in land uses (UPA, EA, IA, GA, URB), total ES offer, total GGP, and municipalities with the optimal graphical representation of the data variability (Fig. 4). Therefore, PCA identified the most important variables which explained the clustering of municipalities with similar land use, total ES and total GGP. The PCA showed a great difference between the variables that contribute to the first and to the second axis (PC1 and PC2). Two PC1 and PC2 were obtained, which accounted for 63% of the total variability. PC1 explained 47% of the variation in the data, and PC2 explained the 16%. Also, PC1 and PC2 accounted for 98% of the total variability (Table 5). Furthermore, eigenvalue (EV) in both components (PC1 and PC2) was superior than 1. All vegetated land uses (EA, IA, UPA, GA) and total ES

offer showed a negative EV which ranged between different values (−0.03 and −0.49) (Table 5). On the other hand, URB and total GGP presented positive EV.

PC1 placed municipalities according to its higher URB use, higher total GGP, and minor total ES offer (Fig. 4). Also, PC1 placed municipalities with higher agricultural uses (EA; IA) in the left and higher total GGP on the right. It can be seen that CABA, Gral. San Martin, La Matanza, La Plata, and Vicente Lopez were the municipalities that contributed the most to total GGP in the MRBA (total GGP values were higher than 4%). On the contrary, the municipalities that presented the lowest total GGP (values under than 1%) were: Berisso, Brandsen, Cañuelas, Exaltation de la Cruz, Gral. Las Heras, Lobos, Gral. Rodríguez, Marcos Paz, Mercedes, Pte. Perón, San Pedro and San Vicente (periurban area). In PC2 the higher and positive EV was GA use (0.75) (Table 5). Also, PC2 presented higher positive

Fig. 3 Total ecosystem services offer (total ES offer: white bars) and total geographic gross product (total GGP: black bars) in each of the evaluated municipalities
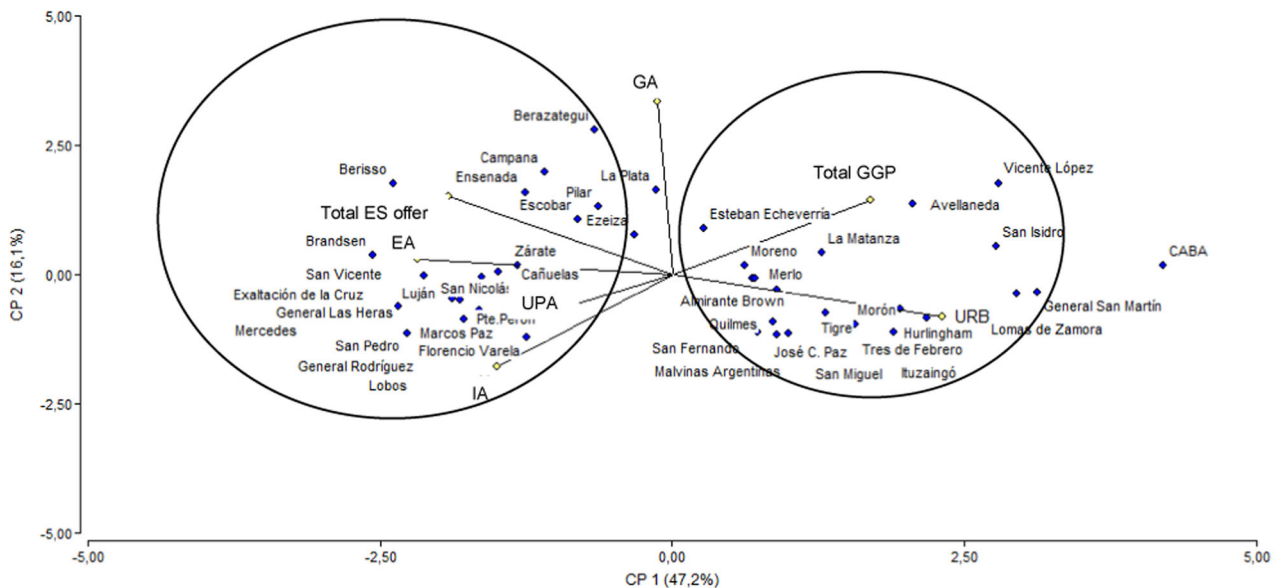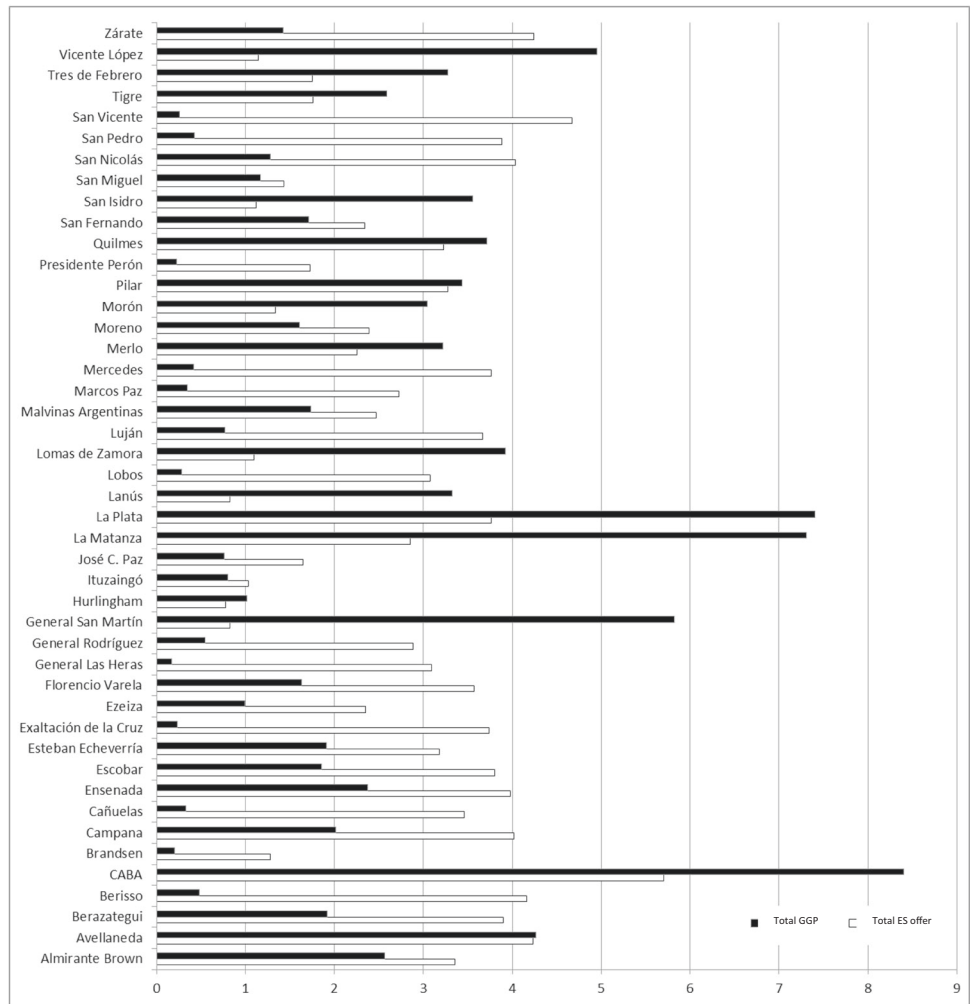

Fig. 4 Biplot of principal components (PCs 1 and 2) representing the distribution of municipalities, total environmental services offer (total ES offer), total geographic gross product (total GGP), and land uses (extensive agriculture EA, intensive agriculture IA, urban and periurban agriculture UPA, green areas GA, urban use URB)

Table 5 Eigenvectors and eigenvalues generated by principal component analysis (PCA) applied on land uses, total environmental services offer (total ES offer), total geographic gross product (total GGP) in the studied area

Eigenvalues				Eigenvectors (EV)		
PC	Value	Proportion	Prop acum	Variables	PC 1	PC 2
1	3.31	0.47	0.47	EA	−0.49	0.07
2	1.13	0.16	0.63	IA	−0.33	−0.4
3	0.98	0.14	0.77	UPA	−0.23	−0.16
4	0.79	0.11	0.89	GA	−0.03	0.75
5	0.49	0.07	0.96	URB	0.52	−0.18
6	0.3	0.04	1.00	Total GGP	0.38	0.32
7	0.01	0.0001	1.00	Total ES offer	−0.43	0.34

Italics values are selected PC1 and PC2 with eigenvalues superior than 1

EA extensive agriculture, *IA* intensive agriculture, *UPA* urban and periurban agriculture, *GA* green areas, *URB* urban use

values for total GGP (0.32) and total ES offer (0.36). PC2 placed at the top of the graph municipalities with higher GA, total ES offer, and total GGP (Vicente Lopez, San Isidro, CABA, Avellaneda, La Plata, Esteban Echeverria, Campana, Berazategui, Berisso, Ensenada, Escobar, Pilar, Ezeiza, La Matanza, Moreno and Merlo). It can be seen that municipalities with the highest percentage of total GGP presented superior URB use and population percentages. On the other hand, the municipalities with minor total GGP presented lower URB percentages (periurban area) and larger agricultural uses percentages (EA, IA) (Table 3). The PCA showed that the heterogeneity between municipalities was largely determined by agricultural (EA; IA) and URB uses, whom finally affected total ES offer and total GGP.

Discussion

Landscape uses in the studied area were related to population increase and the colonization processes beyond new spaces. These generated the replacement of natural ecosystems by agricultural and urban uses (Morello et al. 2003; Civeira 2016) (Table 3) (Naveh and Lieberman 2001, Morello et al. 2003, Civeira 2016; Peng et al. 2017) (Table 3). Landscape spatial and temporal patterns, created by human activities, generated changes in urban ecosystems structure, increased its fragmentation, and affected the availability of the goods and services associated with them (Kremen et al. 2007; Peng et al. 2017) (Tables 3 and 4; Fig. 4). At the beginning of the century, the Pampean Region presented a higher environmental aptitude to provide ES. The latter allowed a broad development of agricultural productive activities in the MRBA. For several years periurban areas presented an abundant supply of natural

resources, such as crops, vegetables, fruits, and firewood, which later were transformed into commercial resources (INTA 2012; Rivas 2010; Civeira 2016). In the last decades, the inaccurate anthropogenic use of MRBA diminished the natural resources and ES provision (such as habitat for different uses, flood control, food provision) (Table 2; Figs. 3, 4). Finally, natural resources and ES degradation affected population life quality in the studied area (Figs. 3, 4) (Morello 2000; Civeira 2016; Rivas 2010). In cities, due to population growth and urbanization, loss and degradation of vegetated areas occurred. This led to a visible deterioration in the functions and ES vegetated uses provide, generating environmental, economic and social problems that could not be solved quickly (Fig. 4) (Collins et al. 2011; Rivas 2010; Morello 2000). As a consequence of a biased socio-environmental analysis and a deficiency in landscape planning, changes in geo hydrological cycle; soil protection, among others ES were affected in the MRBA (Table 3; Fig. 3). Consequently, an appropriate land use policy needs to include ES measurements, as those obtained in this research, in a sustainable landscape planning (Civeira 2016; Collins et al. 2011, Anderson 2009, Morello 2000).

The differential contributions of the vegetated uses (UPA, GA, IA, and EA) to the total ES offer, observed in the results, are particularly important in order to preserve ecosystems functions (Table 4; Figs. 3, 4). Accordingly, many authors have detailed that CO_2 emissions, floods and other environmental problems, could be neutralized with urban agriculture and GA presented in the cities (Pouyat et al. 2002; Szumacher and Malinowska 2013; Peng et al. 2017). Moreover, ES offer variations throughout landscape uses changes, strongly affected urban population, and its socioeconomic indicators (Table 4; Fig. 4) (Szumacher and Malinowska 2013; Peng et al. 2017). Around the world, it has been documented that ES, provided by vegetated uses, in urban areas directly affected life quality of local population (Obuobie et al. 2006; Zezza and Tasciotti 2010). The latter, was observed since urban vegetated uses (IA, EA, GA, and UAP) provide ESs, such as climate regulation, water provision, population recreation and employment, among others (Table 4; Fig. 4) (Szumacher and Malinowska 2013; Sikorski et al. 2008). Therefore, the conservation of land uses which benefit the environment and the society is a great improvement in urban landscapes and the population which inhabits the MRBA and other world megacities (Szumacher and Malinowska 2013).

Avellaneda district, presented elevated ES offer attributed to UPA use (Tables 3, 4), which reflected the importance of the UPA in a highly urbanized municipality (Szumacher and Malinowska 2013). Also, in highly urbanized municipalities, ES offer from GA also improved total ES offer, showing the importance of keeping GA in populated megacities (Table 4; Civeira 2016; Peng et al. 2017;

Szumacher and Malinowska 2013). In periurban municipalities, ES offer was highly related to IA use, which included horticultural crops (e.g., lettuce; tomato). In general, IA products presented higher NAPP (data shown in Civeira 2016) than grain crops (EA) and herbaceous plants or trees from GA (Tables 3, 4). So, in order to keep environmental quality and the ES these uses provide, it is particularly important to conserve these land uses in the cities and their immediate surroundings. These rural–urban boundaries diminishing may alter the ES that these periurban spaces provide, such as water cycle regulation, aquifers recharge, air purification, erosion control, biological corridors establishment, nutrient cycling, among others (Mateucci et al. 2006; Paruelo 2015; Endreny 2018). According to this, Mateucci et al. 2006) observed an increase in air CO_2 (~40% increase) due to city transport and urbanization increase. The latter, showed the relevance of keeping UPA and GA in urbanized areas in order to maintain, or increase, its contribution to air purification, atmospheric composition regulation, and other important ES in megacities, such as the MRBA.

Municipalities with higher EA and IA uses were located near municipalities with highly GGP from industrial manufacturing, demonstrating a spatial connection between these activities in the MRBA (Table 3; Figs. 2, 4) (Peng et al. 2017; Lodola et al. 2013). The latter, corresponded to the historical industrialization process in Argentina, where a shift of the productive activities from the CABA margins towards the nearby municipalities occurred among the last decades (Tables 2, 3; Figs. 2, 4) (Lodola et al. 2013; Rivas 2010; Vidal-Koppman 2014). As seen in the results and the bibliography,

The last decades included important land use changes, which affected the ES offer and the GGP. These land use changes included: agriculture activities expansion (EA, IA), the reduction of historically industrial jurisdictions, and the increase of service activities from central areas (urban) to the periphery (periurban areas). In urban and periurban areas, total ES offer presented a negative relationship with total GGP, this pattern was also observed in other regions of the world. A study in Warsaw city showed a lesser gross product (GDP) generation in the urban area when agriculture, forests, and other vegetated uses were presented together at the same time (Szumacher and Malinowska 2013). Paruelo (2015) observed that, in urbanized areas of Argentina, ES generated by agricultural activities presented a negative relationship with economic indicators of population welfare. This was related to an external appropriation of ES by actors with greater economic and social influence in urbanized regions from Argentina. However, in this context, it is remarkable that CABA still maintains a significant proportion of industrial activities, ES offer, and the highest GGP in the studied region (DPE, 2016; Lodola et al.

2013). So, it can be inferred that, improving the proportion of UPA and GA uses, in urbanized regions, where industrial activities predominate, could maintain or improve ES offer and GGP, at the same time.

Most of the agricultural uses (EA and IA) in the MRBA are located in the periurban area and settled mainly in the peripheral municipalities (Table 3). These agricultural uses (mainly IA) are frequently the business type (~55%) and occupy almost 90% of the agricultural surface in the MRBA (INTA 2012). In contrast, in municipalities with higher urbanization proportion, a lower number of agricultural uses are settled and they are generally the family type which highly contribute to food security in the cities (Peng et al. 2017) (Table 3). Also, these agricultural productions types can be differentiated between those which produce for their own consumption (and eventually sell surpluses) and those that produce mainly, but not exclusively, for the market. In addition, as seen in the results, this family agriculture (IA) are also considered as greater contributors to GGP and ES offer, among other beneficial attributes in the cities, such as employment indicators improvement (Table 4; Figs. 2, 4) (Obschatko et al. 2006; INTA 2012; Peng et al. 2017). Considering IA and EA benefits, land use planning should keep or increase the number of these agricultural uses, in order to improve population life quality and economic welfare in periurban areas of world megacities (Peng et al. 2017).

In MRBA, EA use destination is mainly for agribusiness and exportation, unlike IA use, which is a fundamental portion of population's consumption in the region. Consequently, IA production is marketed through local markets or directly to super and hypermarkets in the MRBA (INTA 2012). Even ~45% of IA are the family type; they only occupy a small part of the MRBA surface (15%), in comparison with the business type that covers the most part of the area (Obschatko et al. 2006) (Table 3). In MRBA, small urban community spaces such as schools or hospitals presented a higher proportion of agricultural production units for self-consumption (mostly UPA) (Obschatko et al. 2006; INTA 2012). There are national and international experiences (Rivas 2010; De Bon et al. 2010; Peng et al. 2017) showing that the development of these self-consumption productions, controlled by non-government organizations or social networks, may increase citizens integration, employment level, and the GGP by bringing opportunities of selling the additional products in local markets (Fig. 2; Table 4). So, a consequence of preserving these small agricultural productions units (UPA) in the megacities, is the positive contribution they made to GGP, total ES offer, and food security for an important part of the population, especially in those urban municipalities with lower economical incomes (Table 3; Figs. 2, 4) (Peng et al. 2017).

In many continents (Africa, Europe, and America), it has been documented that GGP increased when urban agriculture use is carried out in a large proportion (Szumacher and Malinowska 2013; De Bon et al. 2010) (Figs. 2, 4). Also, in some Europe and Latin America countries, where forests uses occupy a large proportion of urban areas, it was documented that they fulfill ecological, social functions (for example NBI increases), and also increased the national GDP (Szumacher and Malinowska 2013; Sikorski et al. 2008; Rivas 2010). Moreover, when forests were used for wood production, they allowed a monetary income, due to the sale of planted trees (ES provision). Evidence from all over the world suggested that urban forests contributed to industry GGP, generating, for example in the US, an augmentation in annual incomes only from arboriculture (Peng et al. 2017). Also, London's urban forest generated economic benefits from 8 million trees, which were harvested annually. Moreover, megacities as Beijing, Buenos Aires, Cairo, Istanbul, Los Angeles, Mexico City, Moscow, Mumbai, and Tokyo, showed important annual profits and other benefits such as augmentation of carbon storage, from forests grown in these metropolitan areas (Table 2; Figs. 2, 3) (Peng et al. 2017).

In Cameroon (Africa), urban, and periurban agriculture (IA and UPA) contributed with a half of the country GGP (De Bon et al. 2010). Correspondingly with the results from our research, the eventually trade of a ES may improve the economics (GGP) for the local population (Figs. 2, 4). Also, in Mexico City, it was observed that urban agrosystems generated an increase in food security and local population incomes, as well as promoted land uses with lower dependence on external inputs (Pérez-Vázquez and Leyva-Trinidad 2015). Agriculture uses (IA, UPA) and GA in urban and periurban spaces generated food production and local citizens employment which improved life quality of the inhabitants (Table 3; Fig. 4) (Szumacher and Malinowska 2013; Sikorski et al. 2008). As a result, these land uses must be included in public policies, in order to achieve a sustainable landscape planning of urbanized areas. Also, an increase in UPA could recover population basic needs, specially in developing countries, which must be enhanced in order to improve GGP, socioeconomic welfare indicators and meet the SDG of the decade (FAO 2016; Pérez-Vázquez and Leyva-Trinidad 2015) (Fig. 4).

MRBA, as other world megacities, is especially vulnerable to changes in environmental conditions, land use, and socioeconomic conditions (Fig. 4). In Bejing area, Peng et al. (2017) observed that urbanization presented a negatively linear relationship with total ES. Moreover, from city center (urban) to peripheries (periurban) it was observed that GGP and urbanization showed a trend of gradual decline (Figs. 2, 3). Since population settlement or urbanization impact on economic indicators (GGP) and ES; in order to improve urban ecological sustainability, land

planners need to control the number and distribution of urban uses (URB) without diminishing the levels of population, economic indicators (GGP), and ES provision (Figs. 2–4. Peng et al. 2017). As seen above, agricultural uses (EA, IA, and UPA) and GA exhibited the capacity to provide ES (Table 3) these landscape uses must be guaranteed in order to improve megacities landscape planning (Table 3) (Fig. 4) (Civeira 2016; Peng et al. 2017). Moreover, it is not only essential to identify and quantify the relationship between ES and GGP (Figs. 3, 4), but also improve ES conservation, in order to achieve an adequate landscape planning for the region that will permit a sustainable environmental and economic use of the urban and periurban ecosystems.

ES provide a key indicator of ecosystem quality (Arbault et al. 2014); therefore, study on its association with urbanization and GGP offer an original integrated progress for quantifying the ecological impact of urbanization and economic variables (Cumming et al. 2014). In addition, recognizing the amount of ES reply to urbanization can explain the stage description of the ecological impact of landscape planning quantitatively. This information supply technical assistance for planning urban ecological sustainability. As verified by this research of the urban and periurban area in MRBA, quantification of ES response to urbanization and GGP were identified using PCA, which demonstrated that municipalities with higher ES offer presented lower GGP amounts. Because of land constructions expand, there was a negative effect between urbanization on ES. So, it is likely to comprehend urban ecological planning by managing the quantity and allocation of urban land building and impermeable surface avoiding significantly diminishing the intensity of vegetated uses and economic indicators (GGP).

The highest levels recognition for the ecological impacts of urbanization is still missing, which is of large importance to landscape planning of urbanization and vegetated uses. Moreover, spatial patterns of urban expansion are changing during urbanization process in the periurban areas. Specifically, urban developing area expands to periurban periphery and into rural area progressively. Therefore, urbanization correlated researches have steadily turned to focalizing on periurban areas, which include the dual characteristics of urban and rural spaces (Peng et al. 2017; Civeira 2016; Yang et al. 2016). On the other hand, in contrast with distinguishing the population impact of urbanization, a small number of researches have determined on the effect of urbanization on ES and GGP in urban and periurban areas (Peng et al. 2017). In municipalities with elevated urban density our research demonstrated the important role of GA and self-consumption agriculture (UPA) in maintaining ES offer. Furthermore, in municipalities where socioeconomic rationalities impact directly in

environmental properties, GA and UPA uses may recover ES, improving conditions for a sustainable urban development. Consequently, districts with a large proportion of environmental problems such as: degraded natural resources, unorganized urban settlements, might be recovered with an adequate vegetated uses (GA, UPA, EA, and IA) arrange, which might contribute to a sustainable landscape planning.

Conclusions

Vegetated uses (EA, IA, GA, and UPA) in urban and periurban areas of the studied region controlled the generation of ES, especially those related to food, energy provision, environmental regulation, among others. Also, preservation of ES is associated with other benefits such as: soil conservation, land uses diversity, recreational activities, and employment generation for urban inhabitants. In addition, agriculture in urban and periurban areas (EA, IA, and UPA) demands considerable labor throughout crops production cycle, since crop rotation is corresponded to more than one season. This greater need of workforce in urban vegetated uses should employ cities residents. The latter will improve ES offer, economic activities, GGP, and inhabitants life quality in urban and periurban areas.

The negative trend between urbanization and ES offer pointed out the effect of land urbanization on ES, this impact seems direct and effective, such as GGP and ES offer negative relationship. In general, the negative effect of urbanization on ES was lower in the periurban area, followed in ascending order by that in the urban area. In accordance to the observed impact between urbanization, GGP and ES, population settlement might be developed by fastening or enhancing land vegetated areas, in order to accomplish urban ecological sustainability with less ES degradation.

The implicit cause in a decision, on the use or conservation, about ES in an area arises from different actors interests, whom exhibit the greatest economic and social power. ES presented a complex matrix of interactions between ecological and a social domains. On the other hand, the interactions between GGP and the social domain occurred differently, depending on economic models, and might be revealed in dissimilar spatial and temporal scales. The MRBA is highly vulnerable to changes in: environmental disorders, land use, and socioeconomic conditions. So, different land uses that present the capacity to provide ES and GGP must be conserved under these categories, in order to improve population's life quality in urban and periurban areas worldwide.

Compliance with ethical standards

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