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Article

Urban agriculture digital planning for the European Union's Green Deal

Amfiteatru Economic Journal

Provided in Cooperation with:

The Bucharest University of Economic Studies

Suggested Citation: Bartolome, Ana M; Carpio, Deiyalí A; Urbano, Beatriz (2022) : Urban agriculture digital planning for the European Union's Green Deal, Amfiteatru Economic Journal, ISSN 2247-9104, The Bucharest University of Economic Studies, Bucharest, Vol. 24, Iss. 59, pp. 159-172,
<https://doi.org/10.24818/EA/2022/59/159>

This Version is available at:

<https://hdl.handle.net/10419/281627>

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URBAN AGRICULTURE DIGITAL PLANNING FOR THE EUROPEAN UNION'S GREEN DEAL

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<p>Please cite this article as: Bartolome, A.M., Carpio, D.A. and Urbano, B., 2022. Urban Agriculture Digital Planning for the European Union's Green Deal. <i>Amfiteatru Economic</i>, 24(59), pp. 159-172.</p> <p>DOI: 10.24818/EA/2022/59/159</p>	<p>Article History Received: 22 September 2021 Revised: 15 November 2021 Accepted: 10 December 2021</p>
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Abstract

Urban agriculture is a nature-based solution recommended for the regeneration and adaptation of urban areas to climate change, in consonance with the European Green Deal. Nevertheless, for the development of urban agriculture, the availability, access and usability of cultivable land in urban areas is of particular concern. This study aimed to use the digital agricultural data geographic information system AGRO-GIS to calculate and predict potential urban agriculture from abandoned horticultural lands and greenhouses in urban areas. In doing so, the variation of agrarian land in urban areas was calculated. A binary logistic regression modelled abandoned horticultural land and greenhouses in urban areas to obtain the determinant factors for potential urban agriculture. Then, an analysis of variance (ANOVA) was used to obtain significant differences in the variation of the agrarian land among urban areas. Results show that an average of 97.85 ha of abandoned horticultural land and greenhouses can provide potential urban cultivable land in cities. The variation of non-irrigated lands and grasslands-shrublands are determinant for potential urban agriculture. A hectare decrease in non-irrigated lands is associated with an 87.98% increase in the odds of potential urban agriculture. An increase of a hectare of grasslands-shrublands increases the likelihood of potential urban agriculture by 67.59%. Furthermore, it is concluded that differentiated planning and management of urban agriculture by urban areas is needed. This study can help urban planners to manage, plan and predict cultivable land for urban agriculture.

Keywords: Potential urban agriculture, land use, binary logistic regression, citizens' well-being, city climate change adaptation, societal demand.

JEL Classification: R11, R14, R52

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Introduction

Urban Agriculture (UA) is defined as horticultural, agricultural and farming activities carried out in and around urban areas. UA is recommended for the regeneration and adaptation of urban areas to climate change and contributes to food security providing social, economic and environmental benefits, in consonance with the European Green Deal. Therefore, the demand for UA in urban areas is increasing worldwide. However, one of the most significant challenges of UA is the access to cultivable land in urban areas. Thus, it is necessary to address issues associated with use, availability, access and usability of cultivable land in urban areas. Furthermore, there is a need to integrate agriculture in the sustainability agenda frame as a main component in future city planning and, in doing so, manage and predict potential agrarian lands in urban areas. Authors have demonstrated that land management digital tools can be a suitable tool for attaining these objectives. Nevertheless, up to date, no previous research work explored agricultural data geographic information system AGRO-GIS to calculate and forecast potential land for UA in urban areas. This study aimed to explore the digital agricultural data geographic information system AGRO-GIS to plan, manage and predict potential UA for the recovery of abandoned agricultural lands and their application to urban areas. This paper is structured as follows. The first part revises the literature on the subject. The second part describes the material and methods of the exploratory analysis of the digital agricultural data geographic information system AGRO-GIS to plan, manage and predict potential UA, including the sampling, fieldwork and the data analysis. In the third part, the results are presented, and the theoretical and managerial implications of the findings are discussed. Finally, the conclusions, practical implications and future research lines are delineated.

1. Literature review

The European Union's Green Deal aims to protect, conserve and enhance the EU's natural capital and protect the health and well-being of citizens from environment-related risks and impacts (European Commission, 2019). In this context, urban agriculture (UA) is a nature-based solution recommended for adaptation to climate change and the regeneration of urban areas (Frantzeskaki, 2019), in consonance with the European Green Deal. In this line, UA preserves and restores the ecosystems and biodiversity in urban areas (von der Leyen, 2019), decreases the urban heat island intensity, improves the air quality, regulates water run-off, offers habitat networks through cities, preserves agricultural knowledge in urban populations, offers increased human health and well-being and contributes to food security providing social, economic and environmental benefits (Speak et al., 2015; Gittleman et al., 2016; Wynne et al., 2020; Puppim de Oliveira and Ahmed, 2021).

Moreover, Artmann and Sartiso (2018) demonstrated that UA contributes to key societal challenges of urbanization such as biodiversity and ecosystem services, agricultural intensification, resource efficiency, urban renewal and regeneration, land management, public health, social cohesion and economic growth. Many gardeners, especially those from urban areas, cultivate to have contact with nature and feel a connection to the land (Park et al., 2019). Community gardens activate the sense of belonging to the community and contact with other neighbours, favouring the creation and strengthening of social networks (Camps-Calvet et al., 2016). Urban community gardens improve social relations and favour reciprocity, mutual trust, common decision-making, civic commitment and community

building, all of which favour both individual and community health (Barriuso and Urbano, 2021). These relationships are also vital to promote healthy lifestyles and strengthened neighbourhoods (Langemeyer et al., 2021). Gardening offers an activity that liberates urban dwellers from an otherwise sedentary lifestyle and from the stress of the city. Community gardens are also leisure spaces, and citizens use these recreational spaces, which protects the health and well-being of citizens (Yu et al., 2019).

Additionally, one of the objectives of the European Union's Green Deal is to propose transformative policies to design a fair, healthy and environmentally friendly food system, from 'Farm to Fork', to which UA contributes. In this line, Wynne et al. (2020) showed that UA is considered as a solution to inadequate food access in cities and provides a source of healthy food. Some families cultivate urban gardens to know what they eat and to avoid the transport and transaction costs of large-scale food distribution. They are moved to reverse the system by consuming products produced locally and by themselves. In this sense, UA contributes to food security by both the quantity and quality of food availability in urban areas (Barriuso and Urbano, 2020). Specifically, UA has been shown to improve the quantity and quality of food available to low-income urban households. Therefore, UA can contribute to an improvement in food security and a reduced reliance on food from rural areas (Nigussie et al., 2021).

The demand for UA in urban areas is increasing worldwide in consonance to its benefits. In London, it has increased fourfold since 2006, and provision would need to increase by 77% in order to address the current length of waiting lists (Fletcher and Collins, 2020). Nevertheless, authors have pointed out that the development of UA must overcome several challenges. For instance, it is required new technologies integrating the Internet of Things (IoT) (Atitallah et al., 2020). Innovations in food production are required which can offer citizens sustainable alternatives that simultaneously address local food security and green infrastructure needs (O'Hara et al., 2021). New business' models supporting both social and technological innovations in UA are needed (Sanyé-Mengual et al., 2019).

Additionally, the authors indicated that the most significant challenges of UA are the regulatory framework and access to suitable lands (Halloran and Magid, 2013; Sarker et al., 2019). For instance, in Southern United States, Fricano and Davis (2019) concluded that land conversion and the lack of economic sustainability are the main barriers to UA. In African cities, Puppim de Oliveira and Ahmed (2021) also showed that problems with UA could be solved by removing perverse incentives, conflicting regulations and unfair land management decision-making systems, along with providing more secure land tenure. Therefore, there is a need to address issues associated with land use, availability, access and usability (Sarker et al., 2019). In this same line, Marat-Mendes et al. (2021) regret that UA has been largely absent of formal recognition in the urban planning policies. Although agriculture has always been a relevant element of city sustainability, it took 55 years to emerge urban planning practices that fully integrate agriculture in cities (Jansma and Wertheim-Heck, 2021). Therefore, there is a need to integrate agriculture in the sustainability agenda frame as a main component in future city planning (Wynne et al., 2020). In doing so, there is a need to manage and predict potential agrarian lands in urban areas among their urban planning. Authors have demonstrated that land management digital tools can be a suitable tool for attaining these objectives. Nigussie et al. (2021) used overlay analysis with multiple criteria in ArcGIS software to search for appropriate locations for UA. They demonstrated that of the bare-lands can be categorized as highly suitable for UA in

Ethiopia 57.2%. Saha and Eckelman (2017) used GIS and remote sensing data to estimate the potential of UA in Boston, screening ground parcels and rooftop areas for UA, despite this, not all ground parcels and rooftops are adequate for agriculture. Dupuy et al. (2020) used landscape zoning based on multisource satellite data to identify agri-urban functional areas in the city and demonstrated its suitability for mapping agriculture and urban land cover. Nduati et al. (2019) used Landsat images and their Normalized Difference Vegetation Index to map and continuously monitor UA in the Tokyo Metropolis. Gottero et al. (2021) used map-based indices to characterize the peri-urban landscape of Turin in Italy, and generated maps of spatial and functional classification at the landscape unit level, obtaining a map of critical areas to improve UA. In all these cases, authors used and combined existing land management digital tools, to plan, manage and predict potential UA. Nevertheless, up to date, no previous research work explored agricultural data geographic information system AGRO-GIS to calculate and forecast potential UA. The agricultural data geographic information system AGRO-GIS is a tool included in the Spatial Data Infrastructure (IDE) of the Spanish Ministry of Agriculture that integrates the data, metadata, services and information of a geographical nature that are the competence of the Ministry, following the specifications of the Open Geospatial Consortium (OGC, 2021). Then, to integrate agriculture in urban planning Sanz Sanz et al. (2017) proposed a methodology to map, characterize and represent homogenous peri-urban agriculture spatial units (USAPU) combining geographical descriptions and agricultural and urban data with statistical analysis, to define a systemic and generic methodology for planning and public action at inter-municipal level. In this line, Sarker et al. (2019) examined current practices and identified existing opportunities and constraints and developed an integration framework of urban agriculture for Australian cities that allow improve sustainability of cities by bringing together the advantages of growing food within a greener urban environment. Furthermore, Contesse et al. (2017) indicated that urban agriculture is an opportunity for urban greening, although in the case of Santiago changes are needed in how green areas are planned and conceived. UA should not be understood as a substitute for parks but as a complementary form of green space provision with a distinctive value.

2. Research methodology

The research questions of this exploratory analysis are the following:

- RQ1: How the agricultural data geographic information system AGRO-GIS can be used to calculate and predict potential urban agriculture?
- RQ2: What are the determinant factors for potential urban agriculture?
- RQ3: Why is digital differentiated planning and management of urban agriculture recommended?

The agricultural data geographic information system AGRO-GIS was used to calculate and predict potential UA. AGRO-GIS is a tool that offers cartographic and alphanumeric information (MAPA, 2021). AGRO-GIS integrates the data, metadata, services and information of a geographical nature that are the competence of the Spanish Ministry of Agriculture Ministry aligning with the objectives of the European directive (INSPIRE, 2014) and the Spatial Data Infrastructure of Spain (IDEE). The agricultural data geographic information system AGRO-GIS offers, i) general cartography, ii) thematic maps on

agroclimatic variables, iii) reports on municipalities and meteorological stations, iv) map of crops and uses of Spain, at 1/50,000 scale and v) reports on 50,000 sheets and municipalities. These public services operate the interoperability of the geographical information of the ministry, its effective inclusion in the IDEE and comply with the provisions of Directive 2007/2 / EC of the European Parliament of the Council called INSPIRE and the Law on infrastructures and geographic information services in Spain (14/2010 of July 5), called LISIGE.

In order to plan, manage and predict UA using AGRO-GIS, a sample of the urban areas in the Castilla y Leon region of Spain was analysed. To select the sample of the urban areas of the region, the classification of urban areas by the Spanish Ministry of Development (2018) was used. The classification characterized forty-seven urban areas in the region. Castilla y Leon is Spain's largest region and the third largest region in Europe, with a territory of 94,225 km². The land use in the region is 31.36% forested land, 36.77% arable lands and permanent crops, 17.81% pastures and mosaics, and 14.06% other lands. It represents over 5% of the country's population (2,418,556 inhabitants in 2018) (Eurostat, 2019). The unemployment rate in Castilla y Leon has continued to decrease from 2013 (when it was at 21.8%), and it was 12.1% in 2018 (Eurostat, 2019). This value is below the national average (15.3%) but above the EU average (6.9%). Furthermore, the regional production sector is widely scattered, with small family firms dominating the market. The main activities in the region in terms of percentage of GDP are tourism and culture (11.8%), construction (8.4%), transport (6.3%) and agriculture (5.1%). The sociodemographic characteristics of the urban areas of the Castilla y Leon region are presented (table no.1).

Table no. 1. Socio-demographic characteristics of the urban areas of the region expressed as minimum, maximum and Mean, Standard Deviation (S.D.) values

Variable	Minimum	Maximum	Mean (S.D.)
Population	1165.0	299715.0	27377.8 (55737.4)
Population over 65 years	91.0	59737.0	6518.9 (14662.2)
Percentage of population over 65 years	1.9	27.8	19.8 (39.5)
Surface (km ²)	943.3	27167.5	5873.5 (6029.8)
Density of population (pop./km ²)	21.0	3671.0	482.9 (759.3)

The digital agricultural data geographic information system AGRO-GIS of the Spanish Ministry of Agriculture (MAPA, 2021) was used to calculate the variation of the agrarian land uses in the urban areas of the Castilla y Leon region. The maps and data of agrarian land uses from 1980-1990 and 2000-2010 were analysed. The agrarian lands were classified into agricultural, livestock and forestry lands. Then, the variation of these lands was calculated. The correlation between the variation of the agricultural land use, other land uses and the sociodemographic characteristic of the urban areas was calculated using the Pearson correlation ($p < 0.05$).

A principal component analysis (PCA) was then used to reduce the variables and eliminate possible multicollinearity among variables (Rahayu et al., 2017). From each component of the PCA, the highest loads of the eigenvectors were selected as predictors. A binary logistic regression was used to model abandoned horticultural lands and greenhouses in the cities, obtaining the determinant factors for potential UA. In the binary logistic regression the log odds of the outcome were modelled as a linear combination of the descriptors. For the data set we deployed a binary response (outcome, dependent) variable called 'potential UA',

which is equal to 1 if the horticultural land and greenhouses have decreased (negative value), and 0 otherwise. Binary logistic regression was used to predict the odds of potential UA, based on the values of the predictors. Regression coefficients were estimated using maximum likelihood estimation and were presented with Wald χ^2 -statistics and as odds ratios, by using the Wald forward stepwise method. The models revealed the most important predictors of potential UA and predicted potential UA.

Finally, an ANOVA analysed the significant differences in the variation of the agrarian land uses among urban areas of the Castilla y Leon region, to determine whether similar or differentiated urban planning of UA by urban regions is required. The statistically significant differences between urban areas’ means were determined (F and p-value). The significance ($p < 0.05$) was obtained using Levene’s test. SPSS v.26 software was used.

3. Results and discussion

Results show that the major decrease in agricultural lands was in non-irrigated lands, with an average of 504.14 ha, followed by horticultural land and greenhouses (97.85 ha) and irrigated lands (73.32 ha). It is noteworthy that in the region an average of 202.37 ha was abandoned and has become unproductive lands. The livestock lands showing a major decrease were grasslands-shrublands, with an average of 55.36 ha. Moreover, forested lands in which conifers predominate decreased by 286.92 ha (table no. 2).

Table no. 2. Variation of the agrarian land in the urban areas of the region, Mean, Standard Deviation (S.D.) expressed in hectares classified in agricultural, livestock and forestry uses

Agricultural use	Mean (S.D.)
Non irrigated lands	-504.1(1132.1)
Horticultural land and greenhouses	-97.8 (311.7)
Irrigated lands	-73.3 (453.3)
Non irrigated vineyards	-30.9 (78.6)
Irrigated orchards	-1.0 (4.7)
Non irrigated orchards	-1.0 (8.5)
Irrigated vineyards	5.7 (21.5)
Unproductive	202.4 (244.3)
Livestock use	
Grasslands associated with hardwoods	-55.4 (255.6)
Grasslands	159.6 (522.9)
Grasslands- shrublands	221.3 (773.3)
Forestry use	
Conifers	-286.9 (1042.5)
Shrublands	-76.9 (683.8)
Poplars	-46.4 (403.8)
Hardwood forests	-41.3 (236.7)
Shrublands associated with conifers	29.4 (48.5)
Shrublands associated with hardwoods	30.2 (154.7)
Shrublands associated conifers and hardwoods	34.6 (95.6)
Water (water bodies, ponds, etc.)	59.4 (122.9)
Other hardwoods	181.0 (423.0)
Conifers associated with hardwoods	312.6 (1081.0)

Results show that the decrease of agricultural lands in urban areas point to the recommendation that vacant lands be recovered as suitable for UA. Abandoned horticultural land and greenhouses, averaging 97.85 ha, can provide urban cultivable land in cities. A negative Pearson correlation was found between the variation of horticultural land and greenhouse crops and unproductive lands amounting to -0.439 ($p < 0.01$). The variation of horticultural land and greenhouses is negatively correlated with the variation of forestry and scrub lands associated with conifers ($r = -0.338$; $p < 0.05$) and scrublands associated with hardwoods ($r = -0.389$; $p < 0.01$).

Table no. 2 answers the first research question that this study sought to address:

- RQ1: How the agricultural data geographic information system AGRO-GIS can be used to calculate and predict potential urban agriculture?

Table no. 2 demonstrates that the agricultural data geographic information system AGRO-GIS allows calculate the variation of agricultural vacant lands suitable for UA to be recovered.

Pearson correlation with the sociodemographic variables showed a negative correlation between the decrease of horticultural lands and greenhouses and the population ($r = -0.574$; $p < 0.01$), and the population older than 65 years ($r = -0.417$; $p < 0.01$). The higher the population that is over 65 years, the lower the decrease of horticultural lands and greenhouses. This result is consonant with municipal occupational programmes that promote UA among elders, and these programmes are consonant with the Silver Economy policy of the European Union that investigates the well-being of older citizens, considering that in Europe, a quarter of the population will be aged 65 and over by 2050 (Grundy and Murphy, 2017). In this sense, the World Health Organization (2015), in its World Report on Aging and Health, defined the concept of healthy ageing to the process of promoting and maintaining functional capacity that allows well-being in old age. The WHO argued that EC Silver Economy policies should consider the active ageing of older people in situations of social vulnerability; knowledge and opportunities for personal, cognitive, biological and physical development and social participation; promoting and balancing personal responsibility; intergenerational encounters and solidarity; and the creation of favourable environments, which provide quality of life and delay levels of dependency. In this line, it has been proved that the physical activity necessitated by UA can contribute to active ageing (Barriuso and Urbano, 2021, Camps-Calvet et al., 2016). Moreover, UA allows the elderly to share time with younger people and communicate with others, combating isolation and providing for the development of social relationships (Freeman et al., 2012). Therefore, elder can benefit from UA with general wellbeing impacts, nutritional health impacts, economic interests, and socialization motivations (Kirby et al., 2021).

The PCA reduction of the variables revealed nine new components that eliminate the possible multicollinearity among variables (table no. 3). From each component of the PCA, the highest loads of the eigenvectors were selected as predictors.

Table no. 3. Loading weights of the principal component analysis of the variables land use and socio-demographic characteristics

Agricultural use	Component number	Weights
Non-irrigated orchards	2	-0.504
Non-irrigated lands	2	-0.715
Irrigated lands	3	0.608
Unproductive	3	0.775
Irrigated orchards	5	0.557
Irrigated vineyards	6	-0.588
Non-irrigated vineyards	6	0.796
Livestock use		
Grasslands associated with hardwoods	3	-0.609
Grasslands	5	0.517
Grasslands- shrublands	8	0.732
Forestry use		
Conifers	1	-0.706
Conifers associated with hardwoods	1	0.718
Water (water bodies, ponds, etc.)	1	0.866
Shrublands associated with conifers and hardwoods	1	0.686
Shrublands associated with conifers	1	0.548
Other hardwoods	1	0.512
Shrublands	4	-0.503
Hardwood forests	5	0.505
Shrublands associated with hardwoods	5	0.478
Poplar	9	-0.554
Socio-demographic characteristics		
Surface (km ²)	1	0.931
Population over 65 years	2	0.659
Density of population (pop./km ²)	2	0.640
Population	2	0.708
Percentage of population over 65 years	7	0.689

Rotated components using varimax.

Then, a binary logistic regression modelled the abandoned horticultural lands and greenhouses as potential UA lands, obtaining the determinant factors for potential UA. Table no. 4 presents the results of the binary logistic regression model with the estimated logistic regression coefficients (β), their respective standard errors (S.E.), Wald χ^2 -statistics, significance levels, odds ratios (Exp(β)) and goodness-of-fit statistics.

Table no. 4. Coefficient estimates and diagnostics from binary logistic regression explaining potential UA

Descriptors	β	S.E.	Wald	Sig.	Exp (β)
Non-irrigated lands	-2.751	1.163	5.595	0.018	15.664
Grasslands-shrublands	1.643	0.773	4.52	0.034	5.172
Constant	-3.255	1.175	7.678	0.006	0.039

The model of potential UA obtained is this:

$$\ln(p/(1-p)) = -3.255 + 2.751 \times \text{Non-irrigated lands} + 1.643 \times \text{Grasslands- shrublands}$$

The variation in non-irrigated lands and grasslands-shrublands was found to have significant effects on potential UA. The estimated coefficient of the predictor of non-irrigated lands was 2.751, and the exponentiated value was 15.664. Considering an initial probability (p) of 0.5 (i.e., 50% probability of potential UA against 50% probability of no potential UA) at a certain value for non-irrigated lands, the corresponding odds of 1 for the UA [$O(UA)$] would be $O(UA) = p / (1 - p)$ for that subject. Since the odds ratio for non-irrigated lands was 15.664 for urban areas, probability of UA against no UA would be 15.6 times higher if the non-irrigated lands decrease by a unit value. Thus, the probability of the potential UA will be 0.9399, which is 87.98% higher than the initial 0.5 probability (Mathew et al., 2009). A one-ha decrease in non-irrigated lands is associated with an 87.98% increase in the odds of potential UA. Operating similarly, an increase of one ha of grasslands-shrublands increases the likelihood of potential UA by 67.59%.

On the one hand, the decrease of non-irrigated lands, which accounts for 85.20% of the farmlands of the region, might mean an increase of UA. The Regional Council reports a decrease of farmers in the region of 27.5% since 2005. Consequently, this decrease of farmers might be translated into potential urban farmers who leave large non-irrigated farms for small subsistence urban gardens during their retirement. Cabo et al. (2014) demonstrated that many urban gardeners in the region come from the migration from rural areas to the city. The migration from rural to urban areas during retirement produces in the cities a large proportion of people who were born and raised in rural areas and feel a nostalgic connection with the land and the wish to cultivate it.

On the other hand, the increase of grasslands-shrublands shows a potential for UA, which can mean an increase of urban livestock farms.

Table no. 4 answers the second research question that this study sought to address:

- RQ2: What are the determinant factors for potential urban agriculture?

Table no. 4 demonstrates that the variation in non-irrigated lands and grasslands-shrublands are determinant on potential UA.

The analysis of variance (ANOVA) of the variation of the agrarian land in the urban areas of the region revealed statistically significant differences between the urban areas of the region in the variation of the horticultural land and greenhouses, grasslands-shrublands, poplars, shrublands associated with conifers and hardwoods, and shrublands associated with conifers (table no. 5). Levene test demonstrated the equality of variances. This result leads to a recommendation for differentiated management (Cabo et al., 2014) of the lands for UA by urban areas of the Castilla y Leon region. Therefore, further research and specific planning for UA in the region is recommended in order to manage and predict the most suitable solution for each urban area (Tapia et al., 2021). This study represents an initial proposal of planning and management, although it shows that further research is required to explore the ways in which urban planning practices emerge in particular urban settings.

Table no. 5. Analysis of variance ANOVA of the agrarian land uses. F and p-value<0.05 indicates the significant differences for each variable among urban areas

Variation of agrarian land use	F	p
Poplars	1078.523	0.024
Horticultural land and greenhouses	1909.034	0.018
Shrublands associated conifers and hardwoods	540.990	0.034
Shrublands associated with conifers	1896369.436	0.001
Grasslands- shrublands	4255.431	0.012

These results can help urban planners to develop policies to promote the formal management of UA and government responsibility for UA (Marat-Mendes et al., 2021). This approach can also help urban planners to assist urban farmers in accessing or using land in urban areas. In this sense, Camps-Calvet et al. (2016) indicated that planners can use other, less formal, means to influence change, to forge alliances between different groups, and to facilitate opportunities for urban farmers to overcome land-related hurdles.

Table no. 5 answers the third research question that this study sought to address:

- RQ3: Why is digital differentiated planning and management of urban agriculture recommended?

Table no. 5 demonstrates variation of the agrarian land revealed statistically significant differences between the urban areas of the region, in the variation of the horticultural land and greenhouses, grasslands-shrublands, poplars, shrublands associated with conifers and hardwoods, and shrublands associated with conifers, recommending a differentiated planning and management of UA by urban areas of the region.

Conclusions

This study aimed to use the digital agricultural data geographic information system AGRO-GIS to plan, manage and predict potential UA recovery of abandoned agrarian lands, and its application to the urban areas of the Castilla y Leon region in Spain. Results show that the major decrease in agricultural land in the region was non-irrigated lands, with an average of 504.14 hectares, followed by horticultural land and greenhouses, with an average decrease of 97.85 ha. It is concluded that those abandoned horticultural lands and greenhouses can provide urban cultivable land for UA. Results demonstrated that the higher the population over 65 years, the lower the decrease in horticultural lands and greenhouses, which is consonant with municipal occupational programmes that promote UA among elders, and also in line with the Silver Economy policy of the European Union. It is demonstrated that the variation of non-irrigated lands and grasslands-shrublands is determinant on potential urban agriculture. A one-ha decrease in non-irrigated lands is associated with an 87.98% increase of potential urban agriculture. Therefore, the retired farmers of non-irrigated lands farms, representing a 27.5% increase since 2005, can become potential urban farmers of small subsistence gardens. An increase of one ha of grasslands-shrubland increases the likelihood of potential UA by 67.59%, indicating the potential development of urban livestock. It is concluded that the agricultural data geographic information system AGRO-GIS can be used to calculate, map and model the abandoned horticultural lands and greenhouses as potential UA lands, obtaining the determinant factors for potential UA and

predicting potential UA. Finally, it is concluded that in the Castilla y Leon region, specific planning for UA is recommended in order to predict and manage the most suitable solution of UA for each urban area.

This study provides specific digital tools for policymakers to set their strategies on UA. The application of this analysis to urban areas is insightful since it provides a pointer for the design of policies which could strengthen UA. It contributes to providing guidance to solve societal challenges using digital tools, and in doing so to fulfil the growing societal demand for UA. Finally, the study contributes to knowledge about the planning of UA in line with the European Union's Green Deal.

This paper has several limitations, one being the difficulty of generalizing the results. The digital tool chosen for investigation is rather specific in relation to many urban areas. However, the study is a first attempt to integrate digital tools in UA planning, and the study enhances the understanding of the role of UA in developing urban planning strategy, despite the fact that there is still a long road for its expansion.

There is a need for future research to validate our findings through additional case studies in other urban areas. It would also be important to conduct more in-depth assessments with regards to the impact of UA, so as to provide further guidance to policymakers. Furthermore, it would be important to examine mechanisms to implement UA. This would be highly important in order to strengthen social and environmental innovation. Future work should also explore the expansion of UA and the creation of a database registering UA lands in cities and regions.

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