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Numéro spécial

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Agriculture / Alimentation / Environnement

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Sommaire

Thomas DAMESTOY, Nicolas BRAULT, Ronan MARREC, Régis WARTELLE, Marie BERNARD & Anne-Maïmiti DULAURENT, 2025 - ***Perception des agriculteurs sur les alternatives aux pesticides : entre intentions et réalité***
Innovations Agronomiques 108, 62-81
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Biodiversity and Urban agriculture: Insights and future directions

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Résumé

L'agriculture urbaine fait l'objet d'une attention croissante en tant qu'élément permettant de favoriser la biodiversité en ville, mais ses impacts précis restent encore mal compris. A travers une synthèse de la littérature scientifique portant sur : (i) l'étude des taxons dans les sites d'agriculture urbaine, (ii) la méthodologie d'échantillonnage des taxons et (iii) les facteurs locaux et paysagers impactant la biodiversité des taxons, cet article vise à comprendre l'impact potentiel de l'agriculture urbaine sur la biodiversité en se concentrant sur 3 taxons clés : les oiseaux, la flore et les arthropodes. Une analyse de la biodiversité de chaque taxon évalué en relation avec les facteurs locaux et paysagers révèle un intérêt croissant pour le rôle de l'agriculture urbaine dans la promotion de la biodiversité. Les résultats indiquent que des parcelles plus grandes, une plus grande diversité végétale et l'hétérogénéité de l'habitat favorisent généralement la biodiversité de tous les taxons. Des biais importants existent cependant dans la littérature, avec une prédominance d'études en Amérique du Nord et en Europe se concentrant sur des formes d'agriculture urbaine non professionnelles, en particulier les jardins communautaires, tandis que les fermes urbaines professionnelles restent peu étudiées. L'étude identifie les facteurs paysagers et locaux comme des influences essentielles sur les résultats en matière de biodiversité, suggérant que le milieu environnant, les pratiques de jardinage et les caractéristiques des parcelles affectent de manière significative la diversité et l'abondance des espèces. Malgré les implications positives de l'agriculture urbaine pour la biodiversité, l'article souligne la nécessité de disposer de méthodologies standardisées et d'une représentation plus large des taxons et des types d'agriculture urbaine dans les recherches futures.

Mots clés : Agriculture Urbaine, Biodiversité, Oiseaux, Flore, Arthropodes

Abstract

Urban agriculture has gained increasing attention as a potential driver of biodiversity in urban landscapes, yet its precise impacts remain inadequately understood. Through a literature review looking at: (i) study of taxa in urban agriculture sites, (ii) taxa sampling methodology and (iii) local and landscape factors, this article aims to understand the potential impact of urban agriculture on biodiversity focusing on three key taxa: birds, flora, and arthropods. A comprehensive analysis of biodiversity measurements of each taxon assessed in relationship with local and landscape factors reveals a growing interest in urban agriculture's role in fostering biodiversity. The findings indicate that larger plots, greater plant diversity, and habitat heterogeneity generally promote biodiversity across taxa. Significant biases exist in the literature, with a predominance of studies in North America and Europe focusing on non-professional urban agricultural forms, particularly community gardens, while professional urban farms remain under-researched. The review identifies landscape and local factors as pivotal influences on biodiversity outcomes, suggesting that the surrounding environment, gardening practices, and plot caracteristics significantly affect species diversity and abundance. Despite the positive implications of urban agriculture for biodiversity, the article underscores the need for standardised methodologies and a broader representation of taxa and urban agricultural types in future research.

Keywords: Urban Agriculture, Biodiversity, Birds, Flora, Arthropods

1. Introduction

Extinctions of species have historically constituted an inherent aspect of the natural world. Nevertheless, the increased influence exerted by human activities on ecosystems has precipitated a notable escalation in extinction rates, thereby adversely impacting ecosystem functionality and human well-being (Johnson *et al*., 2017 ; IPBES, 2019). The contemporary biodiversity crisis is evidenced by a worldwide downturn in species populations and ecosystem quality, particularly pronounced in densely urbanised regions (Simkin *et al*., 2022). The expansion of urban areas directly contributes to habitat destruction and a reduction in species diversity. Projections for future urban development foresee an average 52% decline in species abundance (Li *et al*., 2022). While urbanisation tends to diminish biodiversity, it can also present opportunities for mitigation (Aronson *et al*., 2017). Municipal administrations worldwide are introducing greenery in parks, streets, gardens, and rooftops to counterbalance the adverse effects of urban sprawl. Those initiatives are beneficial for biodiversity as Threlfall *et al*. (2017) observed that undergrowth vegetation and native flora enhance species diversity within urban green spaces. Street afforestation, public gardens, urban parks, urban agriculture can all foster connectivity across urban landscapes and serve as valuable corridors for species (Castelli *et al*., 2021). The latter have seen a notable surge in interest in recent years. This burgeoning interest has catalysed the inception of various urban agricultural initiatives and corresponding research endeavours. Despite the acknowledged multifaceted benefits of urban agriculture in fostering biodiversity within urban landscapes (Clucas *et al*., 2018 ; Fauzia *et al*., 2024), the precise impacts of urban agriculture on biodiversity remain inadequately understood.

Urban agriculture is defined by the Food and Agriculture Organization of the United Nations (Belevi & Baumgartner, 2003) as “the growing of plants and the raising of animals within and around cities” and we consider it here in the diversity of its forms, from community gardens to professional urban farms or social farms, excluding indoor urban agriculture. In view of the diversity of urban agriculture sites and urban ecosystems, a framework of analysis and precise indicators must be determined in order to study the impact of urban agriculture on biodiversity. Within the realm of ecology, three primary indicators—abundance, richness, and diversity—are employed to gauge the influence of biological or environmental factors on organisms. Abundance signifies the total number of individuals within a specific area, whereas species richness denotes the count of distinct species present in the same area. Diversity encapsulates the ecosystem's variety by integrating the richness, abundance of each species, and their distribution within that ecosystem (Delang et Li, 2012). Based on previous empirical work on urban biodiversity and its link to urban agroecosystems (Sorace, 2001 ; Liere et Egerer, 2020 ; Chatelain, 2023), birds, flora and arthropods were chosen to represent biodiversity within the urban agricultural context. Those taxa have been thoroughly studied in cities and seem to best represent urban biodiversity species population inhabiting urban agricultural sites (McKinney, 2008). A specific focus was made on bees given the large number of articles related to their presence in gardens and urban farms, which have been summarised in a systematic review by Rahimi *et al*. (2022). The current article aims to furnish a comprehensive overview of the current scientific understanding regarding urban agriculture and biodiversity at large, with a specific focus on the impacts of urban agriculture on the abundance, richness, and diversity of three key taxa: birds, flora, and arthropods.

The primary objective of this study is to scrutinise existing scientific literature to i) elucidate the existing knowledge on how urban agriculture shapes biodiversity in a general context, ii) pinpoint the principal factors influencing biodiversity within urban agricultural settings, and iii) delineate the effects of urban agriculture on the biodiversity of birds, flora and arthropods.

2. Materials and methods

2.1. Search criteria

We conducted a comprehensive analysis of the scientific literature regarding the impacts of urban agriculture on biodiversity, specifically focusing on four areas of focus: general biodiversity, birds, flora, and arthropods, with particular attention to bees due to the significant increase in research interest in this group. Notably, soil biodiversity was less considered in our analysis because it has been thoroughly investigated in previous research (Joimel *et al*., 2019; Chatelain *et al*., 2023 ; Coulibaly *et al*., 2023). As most studies on biodiversity and urban agriculture have been conducted in North American or European countries (Clucas *et al*., 2018 ; Coulibaly *et al*., 2023 ; Royer *et al*., 2023), the scope of this study was limited to Western countries. Our literature search was conducted in September 2024 using the Ovid, ResearchGate, Google Scholar, and Science Direct databases. Articles were limited to those published after 2000. We did not follow a standardised systematic review process but rather an informal simple search in science databases. The search terms included "urban agriculture" along with keywords related to our four areas of focus: "biodiversity," "birds," "flora" (or "flora diversity") and "plants" (or "plant diversity"), "arthropods" (or "arthropod diversity") and "bees". The search identified over 1,000 articles that were subsequently examined to see if they addressed the study of biodiversity within urban agriculture areas, with the goal of gathering between 5 and 10 articles per area of focus. For each area, we selected the most relevant studies from Western countries based on their titles and abstracts, ensuring that they assessed at least one of the primary indicators (abundance, richness, and diversity) and were conducted in urban agricultural settings. In instances where there were limited articles specifically addressing urban agriculture, we broadened our selection to include studies on other types of urban green spaces. We assessed relevance of the articles drawing on previous reviews and our expertise in these topics and favoured systematic and literature reviews. Given the variability in the relevance of articles across different topics, we ultimately included the following number of studies: five on general biodiversity, five on birds, three on flora, seven on arthropods, and seven on bees.

2.2. Data collection

For each article, we extracted and summarised the following data: 1) Title of the study, 2) Type of publication (e.g., Case Studies Analysis, Literature Review, Systematic Review), 3) Authors, year of publication, and journal, 4) Geographical location, 5) Species/taxa studied, and 6) Key findings, including i) methodology, ii) results, and iii) discussion. Following this initial search, we focused our analysis on specific aspects within the research articles: literature review, study design, main results, discussions, and identified knowledge gaps. All this information was compiled into a table (see Appendix A), facilitating the comparison of relevant research articles across different taxa based on abundance, richness, and diversity in relation to influencing factors.

The literature search was limited to studies from Western countries addressing one of the taxa studied and urban agriculture or other types of urban green spaces, and the characteristics of the resulting bibliography are illustrated in Figure 1. Among the 26 studies assessed (one of them studying two taxa), 6 were published between 2000 and 2010, 10 between 2010 and 2019, and 10 since 2020. This trend indicates a growing interest in the subject over the past few years, consistent with findings from various authors (Clucas *et al*., 2018 ; Evans *et al*., 2022 ; Coulibaly *et al*., 2023). Just 3 systematic reviews were identified, with 2 focusing on general biodiversity and 1 on bees. Meanwhile, there were 6 literature reviews, which covered all the areas of focus except flora. The remaining articles consisted of 17 case studies analysis (one of them studying two taxa), half of which were conducted in North America and half in Europe. These analyses examined a range of urban agricultural settings, with community gardens being the most frequently studied form. Notably, only two articles specifically addressed professional urban farms (Sorace, 2001 ; Delgado *et al*., 2017).

Table 1: Bibliography analysis

Studies for each taxa / Characteristics	Type of article			Year of publication			Concerning case studies analysis							
							Geographical location		Areas assessed					
	Case studies analysis	*Literature review*	*Systematic review*	*2000 to 2010*	*2010 to 2019*	*Since 2020*	*North America*	*Europe*	*Allotment gardens*	*Community gardens*	*Private gardens*	*Different sites through an urban gradient*	*Diverse, including non-professional urban agriculture*	*Diverse, including professional urban agriculture*
General biodiversity (5 studies)														
Clucas *et al.*, 2018			X		X									
Coulibaly *et al.*, 2023		X				X								
Evans *et al.*, 2022			X			X								
Fauzia *et al.*, 2024		X				X								
Royer *et al.*, 2023		X				X								
Birds (5 studies)														
Callaghan *et al.*, 2019	X				X		X					X		
Mayorga *et al.*, 2020	X					X	X			X				
Pierret, 2018	X				X			X			X			
Rodewald, 2016		X			X									
Sorace, 2001	X			X				X						X
Flora (3 studies)														
Joimel *et al.*, 2019	X				X			X	X					
Philpott *et al.*, 2023	X					X	X			X				
Seitz *et al.*, 2021	X					X		X		X				
Arthropods (7 studies)														
Burkman et Gardiner, 2014		X			X									
Chatelain *et al.*, 2023	X					X		X				X		
Delgado *et al.*, 2017	X				X		X							X
Egerer *et al.*, 2017a	X				X		X			X				
Egerer *et al.*, 2017b	X				X		X			X				
Liere et Egerer, 2020		X			X									
Philpott *et al.*, 2023	X					X	X			X				
Arthropods / Focus on bees (7 studies)														
Ahrnée *et al.*, 2009	X			X				X	X					
Andersson *et al.*, 2007	X			X				X					X	
Fetridge *et al.*, 2008	X			X			X				X			
Matteson, 2009	X			X			X			X				
Rahimi *et al.*, 2022			X			X								
Tommasi *et al.*, 2004	X			X			X					X		
Theodorou *et al.*, 2016	X				X			X				X		
TOTAL	18	6	3	6	11	10	10	8	2	7	2	4	1	2

3. Results

3.1. Methods of taxa sampling

In addition to the results of the assessed articles, which will be discussed in the following chapters, we also analysed the methodologies used for taxa sampling in studies conducted on-site. Most of the studies employed either visual identification or trapping methods; however, the specific techniques varied depending on the species or taxa being assessed. An overview of these methods is illustrated in Figure 2, which demonstrates that visual observations were preferred for sampling birds, flora, and flying arthropods, while trapping methods were more suitable for all types of arthropods, with the specific trap type varying according to the arthropod group being studied. In all cases, the methodologies required multiple assessments across different seasons and times of day to ensure comprehensive data collection.

Table 2: Methods of taxa sampling

Taxa/Sampling method	Visual observation	Traps	Participative approach

	Points count/observation	***Transect count***	***Quadrat***	***Sticky traps***	***Pitfall traps***	***Pan traps***	***Hand netting***	***Collaborative observatories***
Birds	(Sorace, 2001) (Mayorga *et al.*, 2020)	(Sorace, 2001)						(Pierret, 2018) (Callaghan *et al.*, 2019)
Flora			(Joimel *et al.*, 2019) (Seitz *et al.*, 2021) (Philpott *et al.*, 2023)					
Arthropods / ladybeetles	(Egerer *et al.*, 2017a) (Egerer *et al.*, 2017b) (Philpott *et al.*, 2023)			(Egerer *et al.*, 2017a) (Egerer *et al.*, 2017b) (Philpott *et al.*, 2023)				
Arthropods / ants					(Egerer *et al.*, 2017b) (Philpott *et al.*, 2023)			
Arthropods / beetles					(Delgado *et al.*, 2017)			
Arthropods / spiders					(Egerer *et al.*, 2017b) (Philpott *et al.*, 2023)			
Arthropods / Focus on bees	(Ahrné *et al.*, 2009) (Theodorou *et al.*, 2016)					(Fetridge *et al.*, 2008) (Ahrné *et al.*, 2009) (Matteson, 2009) (Egerer *et al.*, 2017b) (Philpott *et al.*, 2023)	(Fetridge *et al.*, 2008) (Ahrné *et al.*, 2009) (Matteson, 2009) (Egerer *et al.*, 2017b) (Philpott *et al.*, 2023)	
TOTAL	**7**	**1**	**3**	**3**	**3**	**5**	**5**	**2**

3.2. Main findings

The articles focusing on general biodiversity all aimed to understand the relationship between urban agriculture and biodiversity in scientific publications through literature or systematic reviews, using a broader scope than that used in this article. In fact, the different authors analysed more than hundreds of articles each with a robust research protocol and with no geographical limitations. Thus, the analysis of their results provided a comprehensive overview of the scientific knowledge on the impact of urban agriculture on biodiversity.

Despite the relative increase of studies on urban agriculture and biodiversity after 2013 (Evans *et al.*, 2022 ; Coulibaly *et al.*, 2023), currently only a few studies have been published, and most of them shared common characteristics. Firstly, the articles that examine the issue globally showed that studies have been conducted mostly in North American (Clucas *et al.*, 2018 ; Coulibaly *et al.*, 2023) or European cities (Royer *et al.*, 2023). Secondly, certain taxa have been favoured, studies focusing mostly on bird, plant and invertebrate diversity (Clucas *et al.*, 2018) and less on mammals, reptiles or amphibians (*ibid*), leaving gaps in the general biodiversity scope. Finally, there is also a lack of representation in the forms of urban agriculture assessed. Majority of the studies analysed biodiversity on non-professional forms of urban agriculture (Clucas *et al.*, 2018 ; Royer *et al.*, 2023), community gardens being the most studied form (Royer *et al.*, 2023) while almost nothing is known about professional urban farms (Clucas *et al.*, 2018 ; Royer *et al.*, 2023), urban livestock farming (Royer *et al.*, 2023) or soilless forms (Coulibaly *et al.*, 2023 ; Royer *et al.*, 2023). It is also important to note that most studies were comparing urban agriculture to urban areas and agricultural areas, but only one study has compared different forms of urban agriculture with each other (Clucas *et al.*, 2018). This lack of representation on several contextual and methodological aspects hinders drawing general conclusions.

Additionally, an analysis of the studies' content revealed an important variation in results (Clucas *et al.*, 2018 ; Coulibaly *et al.*, 2023). To explain this variety of results, most studies highlighted that other factors than the type of urban agriculture were playing an important role, such as the location and design of the plot, the types of farming practices or human activities and the surroundings of the plot (Clucas *et al.*, 2018 ; Coulibaly *et al.*, 2023 ; Royer *et al.*, 2023).

The analysis of the studies focusing on the different taxa gave a better understanding of these specific factors influencing biodiversity in urban agricultural plots that have already been studied in the literature. They can be divided into two main categories: landscape factors and local factors.

Landscape factors are characteristics of the surroundings of the urban agricultural plot, and include:

- **surrounding landscapes: i.e. presence of green or urbanised areas in the surrounding environment ;**
- **land use in the urban gradient: some studies compared the benefits for biodiversity in urban agriculture areas compared to natural, agricultural, urban green, green roofs or urban areas ;**
- **ecoregion is another landscape factor which has been used only in one study assessing bird diversity (Mayorga *et al.*, 2020)**

Local factors represent the internal features of the plot and include:

- **imperviousness of the plot ;**
- **plot characteristics: size, agricultural practices/garden management and human activities ;**
- **habitat characteristics: habitat heterogeneity, plant diversity, presence of native plants. Soil characteristics and microclimate are other factors which have been used only in one study assessing plant and collembolan diversity (Joimel *et al.*, 2019) ;**
- **ecosystem relations (predation and competition factors) is another factor which has been used only in one study assessing bird diversity (Sorace, 2001).**

All these factors did not impact the different taxa in the same way and sometimes the responses also differed within the same taxon, illustrating the complex interaction between biodiversity and urban agricultural sites. However, the combination of the contents of the studies allowed us to draw some general conclusions. The cross-referencing results are illustrated in Figure 3. The colour of each box in the table illustrates the impact of the factor on abundance, diversity or richness of the taxa assessed : green (+) means a positive impact; orange (-) a negative one; grey (=) indicates that no impact have been assessed; and purple ($) show a complex impact meaning that not all studies agree or that the precise effects differ according to species. The number behind each symbol indicates the number of studies which found the result.

These results showed that certain taxa and factors have been more assessed than others in the articles surveyed. Birds and bees appeared to be most studied, and mostly local factors were assessed such as the size of the plot (9 articles), the plant diversity (16 articles) and the presence of native plants (6 articles). The imperviousness of the plot (5 articles), the habitat heterogeneity (7 articles) as well as the surrounding landscapes (9 articles) were also quite studied. Among these factors, the size of the plot, the habitat heterogeneity and the plant diversity showed homogeneous results, which therefore allowed us to assume that a larger plot with a diversity of habitats and plants seems beneficial or in the worst case have no effect on most of the taxa assessed (Callaghan *et al.*, 2019; Liere *et al.*, 2020 ; Mayorga *et al.*, 2020 ; Seitz *et al.*, 2021 ; Rahimi *et al.*, 2022 ; Coulibaly *et al.*, 2023 ; Philpott *et al.*, 2023 ; Royer *et al.*, 2023). Plant diversity appeared as the most studied factor as well as the most beneficial for biodiversity, with a high number of studies highlighting the positive impact on biodiversity and no studies showing a negative impact (Rodewald, 2016 ; Callaghan *et al*., 2019; Mayorga *et al*., 2020 ; Seitz *et al*., 2021 ; Rahimi *et al*., 2022 ; Coulibaly *et al*., 2023 ; Philpott *et al*., 2023). However, it was difficult to draw conclusions concerning the plot's imperviousness, some studies showing a negative effect for flora, arthropods and bees (Liere et Egerer, 2020 ; Sietz *et al*., 2021 ; Chatelain *et al*., 2023), while others were inconclusive concerning birds (Mayorga *et al*., 2020) and arthropods (Chatelain *et al*., 2023 ; Philpott *et al*., 2023). The same finding went for the presence of native plants which appeared beneficial for birds and flora (Rodewald, 2016 ; Mayorga *et al*., 2020 ; Seitz *et al*., 2021) but stayed unclear about the impacts on arthropods (Liere et Egerer, 2020 ; Rahimi *et al*., 2022 ; Philpott *et al*., 2023).

Other factors have been less assessed, but the few studies carried out showed uniform results. Thus, less intensive agricultural practices in the plot seemed beneficial for bird and bee biodiversity (Sorace, 2001 ; Pierret, 2018 ; Liere et Egerer, 2020 ; Rahimi *et al*., 2022), as well as less human disturbance for bird and flora biodiversity (Sorace, 2001 ; Joimel *et al*., 2019). The impact of the surrounding landscapes stayed unclear and comparison between urban agriculture and other areas have not been comprehensively studied. Finally, it is also important to note that across all the studies, few negative impacts of the various factors on biodiversity were found, so it can be argued that urban agriculture is more likely to benefit biodiversity than threaten it. Nevertheless, it is crucial to approach these overarching findings with caution, given that the studies primarily indicated significant variations in both the number of studies conducted and their outcomes across different taxonomic groups, as illustrated in Figure 3. Indeed, whereas the biodiversity of birds in cities has been assessed thoroughly, studies conducted in urban agricultural areas were still scarce. In contrast, bee biodiversity has been studied a lot with homogeneous results (Rahimi *et al*., 2022), while studies conducted on arthropods showed diverse results. Finally, the impact of urban agriculture on flora has almost not been assessed

Table 3: Cross-referencing results overview

								ARTHROPODS														
TAXA		**Birds**			**Flora**			**General**			**Ladybeetles**			**Ants**			**Spiders**			**Bees**		
Factors category	**Factors**	*Diversity*	*Abundance*	*Richness*	*Diversity*	*Abundance*	*Richness*	*Diversity*	*Abundance*	*Richness*	*Diversity*	*Abundance*	*Richness*	*Diversity*	*Abundance*	*Richness*	*Diversity*	*Abundance*	*Richness*	*Diversity*	*Abundance*	*Richness*
LANDSCAPE FACTORS																						
Ecoregion		$1	$1																			
Surrounding landscapes	Green areas (including other UA areas)	$1		-1				=1	=1			=2	=2		+1 =1	=1		=1	=1	+2	+2	=1
	Urbanised areas			$1			=1		$1	-1		=2	=2		=1	=1						
Urban agriculture VS other land uses	Natural																					
	Agricultural	+1	+1	+1																		
	Urban green areas	+1	+1	+1			+1															
	Gree																			+1	+1	

	n roofs (including UA)																					
	Urban																		+1 =1		
LOCAL FACTORS																						
Imperviousness	Imperviousness	$1		$1			-1	-1 =1	$1	-1 =1								$2		-1		
Plot characteristics	Larger plots	+1	+1	+1				+3	+1			=1	=1	+1	=1	=1	+1	=1	+1	+2	+2 =2	+1 =1
	Less intensive agricultural practices	+1	+2																	+1	+1	
	Less human disturbance	+1	+1				+1															
Habitat characteristics	Habitat heterogeneity	+2	+2	+1			$1												+1	+1	+1	
	Plant diversity	+4	+1	+1			+1	+5	+2	+1		+1 =1	=1	+1	=1	=1	+1	+1	+1	+3	+4 =1	+2 =1
	Presence of native plants	+1	+2				+1	$1			$1	=1	=1	$1	=1	=1		=1	-1	+1 $1	$1	$1
	Soil characteristics						$1															
	Local climate						$1															
Ecosystem relations	Predation factor		=1																			
	Competition factor		=1																			

Legend colours & marks: green (+)>positive impact; orange (-)>negative impact; grey (=)>neutral impact; purple ($)>complex impact / Numbers refer to the number of articles which give this result

Legend "other area types": Natural (outside the city), Agricultural (outside the city), Urban green areas (urban parks, private gardens, cemeteries etc), Green roofs (planted roofs), Urban (urbanised areas)

NB: UA means Urban Agriculture

Table 4: Impact of indicators on bird biodiversity

TAXA		**BIRDS**		
Factors category	**Factors**	Diversity	Abundance	Richness
LANDSCAPE FACTORS				
Ecoregion		$ (Mayorga *et al.*, 2020)	$ (Mayorga *et al.*, 2020)	
Surrounding landscapes	Green areas (including other UA areas)	$ (Rodewald, 2016)		− (Sorace, 2001)
	Urbanised areas			$ (Mayorga *et al.*, 2020)
Urban agriculture VS other land uses	Agricultural	+ (Sorace, 2001)	+ pest bird species (Sorace, 2001)	+ (Sorace, 2001)
	Urban green areas	+ (Sorace, 2001)	+ decreasing bird species (Sorace, 2001)	+ (Sorace, 2001)
LOCAL FACTORS				
Imperviousness	Imperviousness	$ (Mayorga *et al.*, 2020)		$ (Mayorga *et al.*, 2020)
Plot characteristics	Larger plots	+ (Rodewald, 2016)	+ (Mayorga *et al.*, 2020)	+ (Mayorga *et al.*, 2020)
	Less intensive agricultural practices	+ (Sorace, 2001)	+2 (Sorace, 2001) (Pierret, 2018) + decreasing bird species (Sorace, 2001)	
	Less human disturbance	+ (Sorace, 2001)	+ decreasing bird species (Sorace, 2001)	
Habitat characteristics	Habitat heterogeneity	+2 (Rodewald, 2016) (Callaghan *et al.*, 2019)	+2 (Callaghan *et al.*, 2019) (Mayorga *et al.*, 2020)	+ (Mayorga *et al.*, 2020)
	Plant diversity	+4 (Rodewald, 2016) (Sorace, 2001) (Pierret, 2018) (Callaghan *et al.*, 2019)	+ (Mayorga *et al.*, 2020)	+ (Callaghan *et al.*, 2019)
	Presence of native plants	+ (Rodewald, 2016)	+2 (Rodewald, 2016) (Mayorga *et al.*, 2020)	
Ecosystem relations	Predation factor		= decreasing bird species (Sorace, 2001)	
	Competition factor		= decreasing bird species (Sorace, 2001)	

Legend colours & marks: green (+)>positive impact; orange (-)>negative impact; grey (=)>neutral impact; purple ($)>complex impact

3.3. Results for birds

Among the five studies assessing bird biodiversity, which results are illustrated in Figure 4, three articles focused on urban agriculture (mainly community gardens and urban-agricultural parks), while the other two surveyed private gardens or urban green areas in general.

Even if it was recognised that landscape factors have an impact on bird biodiversity, there was no clear evidence on the direction of those effects. In fact, bird trait composition was influenced by the ecoregion as well as the urban cover around gardens which tended to lower the abundance of insectivores, ground-nesters, and forest-associated birds and promote the abundance of urban-associated birds and birds with higher nesting heights (Mayorga *et al*., 2020). In comparison to other areas, Sorace found that urban agricultural parks favour bird diversity and richness more than agricultural or urban green areas (Sorace, 2001).

Unlike landscape indicators, local indicators have been more studied and showed consistent results. First, results were unanimous on the fact that a larger plot with a diversity of habitats and plants benefits the diversity, abundance and richness of birds (Sorace, 2001 ; Rodewald, 2016 ; Pierret, 2018 ; Callaghan *et al*., 2019; Mayorga *et al*., 2020). Diversity and abundance were also enhanced with less intensive agricultural practices and human disturbance, as well as with the presence of native plants. However, the impact of the imperviousness of the urban agriculture site on diversity or richness showed different results considering the species assessed (Mayorga *et al*., 2020). Thus, the results highlighted the importance of diversity, both in the distribution of green or agricultural spaces in the city, and within the plots themselves (Callaghan *et al*., 2019; Mayorga *et al*., 2020).

3.4. Results for flora

Table 5: Impact of indicators on flora biodiversity

TAXA		FLORA		
Factors category	**Factors**	**Diversity**	**Abundance**	**Richness**
LANDSCAPE FACTORS				
Surrounding landscapes	Urbanised areas			= (Seitz *et al*., 2021)
Urban agriculture VS other land uses	Urban green areas			+ wild species (Seitz *et al*., 2021)
LOCAL FACTORS				
Imperviousness	Imperviousness			– wild plant (Seitz *et al*., 2021)
Plot characteristics	Larger plots	+ on green roofs (Coulibaly *et al*., 2023)		
Plot characteristics	Less human disturbance			+ (Joimel *et al*., 2019)
Plot characteristics	Habitat heterogeneity			§ (Joimel *et al*., 2019)
Habitat characteristics	Plant diversity	+ on green roofs (Coulibaly *et al*., 2023)		+ (Seitz *et al*., 2021)
Habitat characteristics	Presence of native plants			+ wild plant (Seitz *et al*., 2021)
Habitat characteristics	Soil caracteristics			§ (Joimel *et al*., 2019)
Habitat characteristics	Local climate			§ (Joimel *et al*., 2019)

Legend colours & marks: green (+)>positive impact; orange (-)>negative impact; grey (=)>neutral impact; purple ($)>complex impact

Of the three taxa studied, flora appeared to be the one for which the effects of urban agriculture have been studied the least, with only a few articles focusing on actual urban agricultural sites. The results of these studies are illustrated in Figure 5. Studies appeared to focus on managed biodiversity rather than non-managed (Clucas *et al*., 2018 ; Royer *et al*., 2023) and the articles assessed showed varied results which, combined with the lack of data, made it difficult to draw firm conclusions. Firstly, urban agricultural sites seemed to host a diversity of cultivated and wild plant species, with which richness was positively related (Seitz *et al*., 2021). Urban gardens were also recognised as hosting endangered or extinct wild growing plants which make them important for nature conservation (Joimel *et al*., 2019;

Seitz *et al.*, 2021). However, the distribution of exotic spontaneous plants in comparison to native plants remained unclear, with contradictory results depending on the study (Joimel *et al.*, 2019; Philpott *et al.*, 2023), and plant richness seemed lower in community gardens than in domestic gardens (Seitz *et al.*, 2023).

Even if Joimel *et al.* (2019) stated that plant diversity seemed to be impacted by local and landscape factors, there is almost no empirical data on landscapes factors. Seitz *et al.* (2021) argued that plant richness appeared independent of the interaction between local and landscape scale imperviousness (Seitz *et al.*, 2021).

At the plot level, less human disturbance and a higher plant diversity appeared to favour flora richness (Joimel *et al.*, 2019; Seitz *et al.*, 2021). A study made on green roofs showed that a larger plot was also beneficial for flora diversity (Coulibaly *et al.*, 2023). Concerning specifically wild plants, imperviousness seemed to hinder richness whereas the presence of native plants favoured it (Seitz *et al.*, 2021). Habitat heterogeneity, soils characteristics and local climate have been identified as other factors likely to affect plant richness but there was no clear consensus on their precise impact on flora (Joimel *et al.*, 2019).

3.5. Results for arthropods

Several studies assessed the effects of urban agriculture on arthropods, as illustrated in Figure 6, showing they were impacted by landscape and local factors (Egerer *et al.*, 2017b; Liere et Egerer, 2020 ; Philpott *et al.*, 2023). However, the impacts depended on the organism's life history traits and habits (*Egerer et al., 2017b; Liere et Egerer, 2020 ; Philpott et al., 2023)* and varied a lot depending on the arthropod groups.

First, larger plots and better plant diversity seemed to enhance arthropods diversity (Liere et Egerer, 2020 ; Coulibaly *et al.*, 2023 ; Philpott *et al.*, 2023) and predators and parasitoids abundance and richness (Burkman and Gardiner, 2014 ; Delgado de la Flor *et al.*, 2017). However, studies showed contradictory results on the effects of the presence of native plants (Liere at al., 2020). The presence of green areas around the plot did not seem to impact diversity and abundance (Egerer *et al.*, 2017b), while the proximity to urbanised areas negatively impacted the richness (Chatelain *et al.*, 2023). The effects of imperviousness at the plot level differed a lot depending on the arthropod group: it was negative for the diversity and richness of canopy or bush layer arthropods, particularly the wingless groups, and had no effect on the diversity and richness of arthropods living on tree barks (*ibid*).

If we look specifically at the three most studied taxa apart from bees which are ladybeetles, ants and spiders, a bigger plot appeared beneficial for ant and spider diversity and non-native spider richness (Philpott *et al.*, 2023). In the same way, a diversity of plants inside the plot was described as positive for ladybeetles abundance and richness (Egerer *et al.*, 2017b; Philpott *et al.*, 2023), ant diversity, spider diversity and richness, as well as non-native spider abundance, showing no effect on ant abundance and richness (Philpott *et al.*, 2023). However, the size of the plot as well as the presence of native plants did not seem to impact ladybeetle and ant abundance as well as richness and spider abundance (*ibid*). The surrounding landscapes showed no impacts on abundance and richness, except for native ants (*ibid*), and the impacts of the plot's imperviousness have been studied only for spiders for which it seemed to depend on the family (Chatelain *et al.*, 2023 ; Philpott *et al.*, 2023).

In contrast to the taxa presented above, bee biodiversity in urban agricultural sites has been quite studied, in particular in a systematic review written by Rahimi *et al.* (2022). At the landscape scale, several studies indicated that the proximity of green areas seemed to enhance diversity and abundance of bees (Hernandez *et al.*, 2009; Rahimi *et al.*, 2022 ; Philpott *et al.*, 2023), showing no effect on richness (Philpott *et al.*, 2023). Contradictory results were expressed concerning the comparison between urban agriculture and urban areas, one systematic review indicating that bee diversity was better in urban agricultural areas (Clucas *et al.*, 2018) while another one argued the opposite (Rahimi *et* *al*., 2022). At the plot's level, results were quite similar as the ones for birds. Indeed, according to most studies a larger plot and a diversity of plants favoured the diversity, abundance and richness of bees (Tommasi *et al*., 2004 ; Andersson *et al*., 2007 ; Arhné *et al*., 2009; Liere et Egerer, 2020 ; Rahimi *et al*., 2022 ; Philpott *et al*., 2023). Less intensive agricultural practices as well as a diverse habitat also appeared beneficial for diversity and abundance (Tommasi *et al*., 2004 ; Liere et Egerer, 2020 ; Rahimi *et al*., 2022). However, studies on the effects of the presence of native plants did not give clear results (Philpott *et al*., 2023), even if one systematic review stated that it is beneficial for bee diversity (Rahimi *et al*., 2022).

To conclude, the studies argued that, at the landscape level, urbanisation had a negative impact on wingless arthropods but almost no effect on flying insects (Chatelain *et al*., 2023). At the plot level, other indicators describing the functional diversity and composition of plant traits (growth form, floral attraction etc.) could have been better metrics to assess the influence of plants on arthropods (Philpott *et al*., 2023).

Figure 6: Impact of indicators on arthropod biodiversity

TAXA		**ARTHROPODS**														
		General			**Ladybeetles**			**Ants**			**Spiders**			**Bees**		
Factors category	**Factors**	*Diversity*	*Abundance*	*Richness*	*Diversity*	*Abundance*	*Richness*	*Diversity*	*Abundance*	*Richness*	*Diversity*	*Abundance*	*Richness*	*Diversity*	*Abundance*	*Richness*
LANDSCAPE FACTORS																
Surrounding landscapes	Green areas (including other UA areas)	= (Egerer *et al*, 2017b)	= (Egerer *et al*, 2017b)			= (Philpott *et al*., 2023) (Egerer *et al*., 2017b)	= (Philpott *et al*., 2023) (Egerer *et al*., 2017b)		- (Philpott *et al*., 2023) + Native ants (Philpott *et al*. 2023)	= (Philpott *et al*., 2023)		= (Philpott *et al*., 2023)	= (Philpott *et al*., 2023)	+2 (Hernandez *et al*., 2009) Non native bees (Philpott, 2023)	+2+SR (Rahimi *et al*. 2022) (Philpott *et al*., 2023)	= (Philpott *et al*., 2023)
	Urbanised areas		$ (Chatelain *et al*., 2023)	- (Chatelain *et al*., 2023)		= (Philpott *et al*., 2023) (Egerer *et al*., 2017b)	= (Philpott *et al*., 2023) (Egerer *et al*., 2017b)		= (Philpott *et al*., 2023)	= (Philpott *et al*., 2023)						
Urban agriculture VS other land uses	Green roofs (including UA)													+ (Rahimi *et al*., 2022)	+ (Rahimi *et al*., 2022)	
	Urban													+ (Clucas *et al*.,		

														2018) - (Rahimi *et al.*, 2022)		
LOCAL FACTORS																
Imperviousness	Imperviousness	Canopy or bush layer artthropods, particularly wingless groups = Tree bark arthropods (Chatelain *et al.*, 2023)	$ (Chatelain *et al.*, 2023	Canopy or bush layer artthropods, particularly wingless groups = Tree bark arthropods (Chatelain *et al.*, 2023)								$ (Chatelain *et al.*, 2023) (Philpott *et al.*, 2023)		(Liere *et al.*, 2020)		
Plot caracteristics	Larger plots	+2 (Philpott *et al.*, 2023) + Natural enemies (predators and parasitoids) (Burkman and Gardiner, 2014) + on green roofs (Coulibaly *et al.*, 2023)	+ Predators and parasitoids (Burkman and Gardiner, 2014)			= (Philpott *et al.*, 2023	- Non native ladybeetles (Philpott, 2023)	+ (Philpott *et al.*, 2023)	= (Philpott *et al.*, 2023)	= (Philpott, 2023)	+ (Philpott, 2023)	= (Philpott, 2023)	+ Non native spiders (Philpott, 2023)	+ (Philpott, 2023) (Liere *et al.*, 2020)	= (Royer *et al.*, 2023) + (Rahimi *et al.*, 2022) (Philpott *et al.*, 2023)	= (Royer *et al.*, 2023) + (Philpott *et al.*, 2023)
	Less intensive													+ (Liere *et al.*,	+ (Rahimi *et*	

	agricultural practices													2020)	*al.*, 2022)	
Habitat caracteristics	Habitat heterogeneity												+ (Otoshi *et al.*, 2015)	+ Bumblebee (Tamasi *et al.*, 2004)	+ (Rahimi *et al.*, 2022)	
	Plant diversity	+4 (Philpott *et al.*, 2023) (Liere *et al.*, 2020) Pollinators other than bees (Liere *et al.*, 2020) Predators and parasitoids (Burkman and Gardiner, 2014) on green roofs (Coulibaly *et al.*, 2023)	+2 Predators and parasitoids (Burkman and Gardiner, 2014) (Delgado de la Flor *et al.*, 2017)	+ Predators and parasitoids (Delgado de la Flor *et al.*, 2017)		+ (Egerer *et al.*, 2017b) = (Philpott *et al.*, 2023	+ (Philpott *et al.*, 2023)	+ (Philpott *et al.*, 2023)	= (Philpott *et al.*, 2023)	= (Philpott *et al.*, 2023)	+ (Philpott *et al.*, 2023)	+ Non native spiders (Philpott *et al.*, 2023)	+ (Philpott *et al.*, 2023)	+ (Liere *et al.*, 2020) Bumblebee (Tomasi *et al.*, 2004) (	+ (Rahimi *et al.*, 2022) Bumblebee (Tomasi *et al.*, 2004) (Andersson *et al.*, 2007) (Ahrné *et al.*, 2009) - (Philpott *et al.*, 2023)	= (Philpott *et al.*, 2023) + (Liere *et al.*, 2020) (Ahrné *et al.*, 2009)
	Presence of native plants	$ (Liere *et al.*, 2020°			$ (Philpott *et al.*, 2023)	= (Philpott *et al.*, 2023)	= (Philpott *et al.*, 2023)	$ (Philpott *et al.*, 2023)	= (Philpott *et al.*, 2023)	= (Philpott *et al.*, 2023)		= (Philpott *et al.*, 2023)	- Native spiders (Philpott *et al.*, 2023)	+ (Rahimi *et al.*, 2022) $ (Philpott, 2023)	$ (Philpott *et al.*, 2023)	$ (Philpott *et al.*, 2023)

Legend colours & marks: green (+)>positive impact; orange (-)>negative impact; grey (=)>neutral impact; purple ($)>complex impact

4. Discussion

The studies assessed and their content analysis suggest that community and allotment gardens in urban areas are rich in biodiversity. Overall, urban agriculture appears capable of supporting a diverse range of animal and plant species (Joimel *et al*., 2019; Royer *et al*., 2023 ; Fauzia *et al*., 2024). However, empirical data demonstrating these beneficial effects on the diversity, abundance, and richness of flora and fauna taxa remain scarce in the scientific literature (Clucas *et al*., 2018). The absence of a common definition for urban agriculture, along with the variability of sites and taxa studied, complicates the comparison of findings across different studies (*ibid*). Additionally, comparing various forms of urban agriculture is challenging, as biodiversity is influenced by spatial, functional, and organisational factors that can vary significantly even within the same type of urban agriculture (Royer *et al*., 2023). Acknowledging this methodological variability, our study aligns with the recommendations of Clucas *et al*. (2018) to develop standardised methodologies. More research is essential to deepen our understanding of the impacts of urban agriculture on biodiversity, with the establishment of common indicators and definitions for different forms of urban agriculture being crucial for producing comparable results in future studies. The use of participatory science via collaborative observatories represents a compelling avenue of inquiry. While this approach notably augments both the volume of generated data and the range of investigated subjects, it also introduces substantial biases and constrains longitudinal data monitoring (Pierret, 2018).

The methodology employed in this review carries several biases. First, the limited number of selected articles makes it difficult to generalise their findings. This small number of selected studies can be explained by the decision to remain general at the taxon level, rather than going into detail about specific genera or species, and it corroborates the results of studies showing that the impact of urban agriculture on biodiversity remains understudied (Clucas *et al*., 2018, Royer *et al*., 2023). Second, we did not include grey literature, and all selected articles were from Western countries and published in English, resulting in both scientific and geographical biases. Additionally, restricting our search to specific keywords may have further hindered our ability to uncover additional relevant resources. Lastly, cross-referencing results from various studies, which are not always directly comparable, necessitates simplification of the findings, potentially compromising their precision and robustness.

Despite these challenges, a general conclusion emerges from our analysis of scientific literature: most articles indicate that larger plots, greater plant diversity, and, to a lesser extent, improved habitat heterogeneity positively influence the biodiversity of the taxa assessed. The predominance of positive impacts over negative ones, likely influenced by the methodological factors discussed, supports the notion that urban agriculture tends to benefit biodiversity rather than decrease it.

This analysis also highlights the importance of considering various local and landscape factors linked to the physical and technical characteristics of the assessed areas. Several studies have underlined that local factor, particularly those related to spatial dynamics and activities, are intertwined with the historical and social contexts of the plots (Clucas *et al*., 2018 ; Joimel *et al*., 2019; Seitz *et al*., 2021). The history of a plot, along with the sociological profiles of gardeners, influences garden management, human disturbance, and habitat characteristics, which are significantly shaped by crop choices (Clucas *et al*., 2018 ; Consalès, 2004 ; Loram *et al*., 2008 ; Seitz *et al*., 2021). However, the ways in which these historical and social factors affect biodiversity in urban agricultural contexts warrant further investigation to enhance our understanding of these interactions (Liere & Egerer, 2020).

Finally, our analysis reveals that the impacts of urban agriculture on biodiversity have received limited attention from the scientific community (Royer *et al*., 2023). This may stem from the hypothesis that the study of urban agriculture and biodiversity remains a grey area for researchers. An examination of the literature indicates that biodiversity in agricultural systems is often seen as distinct from general biodiversity. While "wild" or "hosted" diversity is explored within the realm of ecology, agrobiodiversity typically falls under the domains of social sciences and agronomy (Royer *et al*., 2023). This trend may be even more pronounced in urban agriculture, given its predominantly urban and social perspective, which may overshadow its significance for biodiversity. Consequently, urban agriculture is primarily addressed by social sciences, with limited engagement from the natural sciences (Clucas *et al*., 2018), relegating the subject of biodiversity in urban agriculture back into a scientific grey area.

5. Conclusion

In conclusion, despite the adverse effects of urbanisation on biodiversity, urban agricultural sites appear to positively impact various taxonomic groups. However, the precise effects of urban agriculture on these groups remain unclear, with certain taxa receiving more attention than others. Several recommendations can be made to enhance the effectiveness of urban agriculture as a promoter of biodiversity. Specifically, larger plots and a diverse composition of vegetation should be prioritised to create a variety of ecological habitats. In addition, we would recommend that hedges, fruit trees and an increase in scattered grass cover, woody plants and floral resources are established to increase microhabitat heterogeneity and support biodiversity in gardens. Overall, promoting and raising awareness of agroecological practices in urban agricultural projects, as well as the synergies between crops and functional biodiversity, seems to be an avenue for improving biodiversity. Due to the diversity and variability of factors influencing biodiversity, we also encourage the implementation of biodiversity studies at plot level. These studies provide a better understanding of the on-site biodiversity, as well as that which is lacking, and will define the specific amenities needed to foster it. Although this topic was not covered in this article, soil biodiversity also plays an important role, and implementing management practices that improve soil quality and heterogeneity would also help enhance general biodiversity (Joimel *et al*., 2019). Creating a network of diverse urban agricultural areas and green spaces throughout the city, which allow ecological corridors to pass through, is also a solution for promoting biodiversity in urban agricultural sites and cities in general, as it maintains high habitat heterogeneity. The surrounding landscape and the different types of urban green spaces within the city can provide a better understanding of biodiversity needs in terms of food, habitat and reproductive requirements enabling optimal layout and management of the site.

Overall, more research is needed to better understand the impact of urban agriculture on biodiversity. To address the current lack of representation, future studies should consider a broader diversity of species and taxa (Clucas *et al*., 2018), clarify and evaluate the distinctions between native and exotic biodiversity (*ibid*) and include a wider range of urban agriculture forms (*ibid*; Royer *et al*., 2023). To ensure a better understanding of the results, it is also important for studies to include systematic comparisons between different urban agricultural settings, as well as comparisons with urban or rural environments (Clucas *et al*., 2018 ; Liere et Egerer, 2020 ; Royer *et al*., 2023). Long-term studies would also be beneficial in assessing the transition from agricultural or urban sites to urban agriculture on biodiversity (Clucas *et al*., 2018 ; Coulibaly *et al*., 2023 ; Royer *et al*., 2023).Most importantly, a standardised approach should be developed to incorporate more precise criteria including location, internal organisation, functional and spatial dynamics, and human disturbance (Clucas *et al*., 2018 ; Royer *et al*., 2023). These criteria should be defined and shared collectively and include various levels of detail in order to be adapted for different taxa and qualify more precisely the differences in reactions between species and genders. The development of criteria in collaboration with field actors through action or applied research is also an avenue for future studies. By addressing these areas, we can enhance our understanding of urban agriculture's role in fostering biodiversity and inform better practices for its implementation.

Ethics

The authors declare that the experiments were carried out in compliance with the applicable national regulations.