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Epigeal fauna of urban food production sites show no obvious relationships with area or soil characteristics

Sofia Biffi[a], Cleandho M. De Souza[b], Les G. Firbank[a]*

[a] School of Biology, University of Leeds, LS9 2JT, UK

[b] Faculty of Architecture and Urbanism, University of São Paulo, Brazil, Rua do Lago, 876 - Butantã, São Paulo, 05508-080, Brazil

*Corresponding Author at School of Biology, University of Leeds, LS9 2JT, UK.

Email address l.firbank@leeds.ac.uk

Abstract

Urban food production is a growing area of interest as a way of increasing food security, social capital and biodiversity. As food production relies upon ecosystem services provided by invertebrates (e.g. decomposition), it is important to understand the underlying factors affecting their distribution. Here we investigated soil characteristics influencing the abundance and diversity of epigeal invertebrates. Seventeen sites of different size from in and around Leeds, UK, were selected from an open source database on urban food production sites. Pitfall traps were placed along transects to collect beetles, springtails, and spiders. These invertebrates were identified and counted, adjusting total counts for the number of traps used at each location. Soil samples from the trap locations at each site were homogenized, dried, and analysed to measure organic carbon content, moisture content, and pH, while productivity was assessed by growing radish Raphanus sativus on the soils under uniform conditions. This study found no evidence of correlation of epigeal abundance and diversity with site area or soil characteristics. These findings suggest that there is no evidence as yet of urban food production sites that are too small to be able to draw upon ecosystem services delivered by epigeal invertebrates.

Keywords urban biodiversity; species-area relationships; soil biodiversity; green infrastructure; gardens

Research highlight

- We investigated the effects of soil characteristics and area of urban food production areas on soil surface invertebrates (springtails, spiders, and ground beetles) in the medium-sized city of Leeds, UK
- No relationships were found between epigeal invertebrate number and diversity and the soil characteristics or area of urban food production areas

1. Introduction

The potential of outdoor urban food production areas (gardens, allotments and urban farms) to contribute to sustainable urban food systems is being increasingly recognised (De Bon et al., 2010; Haberman et al., 2014). Urban gardens are specialist environments; they are generally very fertile, with a high organic matter content, as they have been subject to inputs of fertilisers, composts and topsoil (Guilland et al., 2018). Food production from such sites depends upon ecosystem services delivered by invertebrates, including pollination (Foster et al., 2017) and decomposition (Tresch et al., 2019). While we have much to learn about the relationships between urban agriculture and biodiversity (Clucas et al., 2018), we are starting to understand how invertebrates populate urban land (Jones and Leather, 2012). For example, the distribution of woodlice and other arthropods varies along an urban-rural interface (Nagy et al., 2018) and with habitat complexity (McIntyre et al., 2001), while habitat quality and area affect carabids and spiders in urban grasslands (Buchholz et al., 2018), and Hemiptera on roundabouts (Helden and Leather, 2004).

Here we address the interactive effects of habitat character and size as determinants of the abundance and diversity of soil surface invertebrates on urban food production sites in and around the medium-sized English city of Leeds. These factors were chosen as they are most within the control of urban food producers themselves, while soil surface invertebrates were chosen for their roles as ecological indicators (Brooks et al., 2012) and their trophic functions (Nagy et al., 2018).

2. Methods

Seventeen public urban allotment sites were randomly selected from an open source database on local food production in and around Leeds, UK (Bliss 2015, App. Tab. 1). At each site, sampling took place between 18th August 2015 and 25th September 2015, during the active period of ground beetles, which, in the UK, spans between April and October. The average temperature for the month of sampling was 12.6 ℃, average humidity was 87%, and average rainfall 0.77 mm. At each, the land use surrounding the growing beds was noted but was usually mown grass. Pitfall traps were placed into the soil along four perpendicular transects from the edge towards the centre of the cultivated area, thus including potential variability in invertebrate abundance between the edge and the centre of the plot. Pitfalls were placed at distances of 0.2, 2, 4, 8 and 16 metres from the cultivated area edge depending on patch size, and no closer than 0.2 m from other traps, following Firbank et al. (2003). This meant that the smaller patches had fewer traps (Fig. 1, App. Tab.1). The traps consisted of plastic cups (diameter 7 cm, height 15 cm) sunk into the ground, flush with the soil surface, and partly filled with 10% saline solution to preserve the specimens, and unscented detergent to reduce surface tension. After 14 days, the pitfall contents were retrieved from each site and the specimens counted. Carabids were identified to species level (using Chinery 1993; Luff 2007; Benish 2007); more than 50 individuals of three species of Carabidae (Lamostenus terricola, Nebria brevicollis, and Thalassophilus longicornis) were recorded across the sites, allowing them to be analysed separately. Total numbers of Araneae and Collembola were also recorded. There were too few invertebrates in other groups for further consideration. The geometric mean of counts per site was calculated before the analysis. These adjusted counts were here assumed to give estimates of both abundance and activity density.

Soil samples (1 kg) from the first trap location of each transect were removed, homogenized, analysed and dried. Soil moisture content was recorded, soil organic carbon (SOC) content was analysed using loss on ignition following Hoogsteen et al. (2015), and soil pH was assessed following ISO 10013 (British Standard 2005).

Soil productivity was evaluated by growing radish Raphanus sativus var. Malaga in soil samples in a glasshouse. The soil from each site was sterilised at 121℃, 2 atm, for over 126 min following Williams-Linera & Ewel (1984). 300 cm^3 of soil from each site was mixed and placed into four pots, into each of which four radish seeds were sown and thinned down to two after 7 days. These were grown on for 28 days on 16 h/8 h light-dark regime at constant temperature of 20℃, then harvested roots an d shoots dry weighed. Total biomass and root:shoot ratio were used as measures of soil productivity, the latter as it measures biomass allocation considering the whole plant at once (Poorter et al. 2012; Zaki et al. 2012).

Statistical analysis was carried out with the R statistical software version 3.3.2 (Ihaka & Gentleman 1996). Correlations were undertaken using Holm multiple comparison to adjust the significance values for the large numbers of analyses (McLeod, 2011): Multivariate analysis was undertaken to investigate whether soil characteristics were associated with differences in Collembola, Araneae and Coleoptera abundance. A PERMANOVA (999 permutations) was performed using the adonis function in the R package vegan (Oksanen, 2019). The distribution of the data was visualised using an nMDS plot.

3. Results and discussion

The cultivated area on the sampled sites ranged between from 9.6 to 6,480.5 m^2. Soil pH ranged from 6.18 to 7.87 (mean 7.01; SD 0.46) and soil organic carbon (SOC) ranged from 0.14 to 0.62 Kg m^{-3} (mean 0.33; SD 0.10), in general lower than values previously reported in garden soils in the nearby city of Sheffield ((Edmondson et al., 2014). For soil productivity, radish total biomass varied between 7.16 and 9.10 g (mean 7.60 g, SD 0.46), and root:shoot ratio varied from 0.98 to 1.45 (mean 1.08; SD 0.10). The only significant correlation among these soil-related variables was between soil moisture and SOC ($r = 0.82$, $n=17$, $p<0.001$): these results presumably reflected the homogenisation of soils resulting from gardening.

A total of 16,957 invertebrates were sampled from these sites, including 11,168 Collembola, 1,989 Araneae, and 2,643 Coleoptera, of which 1,688 were Carabidae. Individuals of Nebria brevicollis, Lamostenus terricola, and Thalassophilus longicornis accounted respectively for 70%, 19%, and 5% of the total Carabidae catch. The remaining 953 coleoptera were distributed among 8 other families.

There were no significant correlations among cultivated area, pH, SOC, and root:shoot ratio and Aranae, Coleoptera, and Collembola abundance (Tab. 1). There was no significant correlation between the cultivated area with the total number of Carabidae species (tau-b = 0.06, Fig. 2a) nor with total counts of Carabidae per pitfall trap (tau-b = 0.07, Fig. 2b). The strongest correlations were found between soil pH and the abundance of Nebria brevicollis (tau-b = -0.54), and between SOC and SMC (tau-b = 0.53). Both results are consistent with previous work; Nebria brevicollis is known to prefer acidic soils (Sadler et al., 2006), while SOC is an established component of SMC variability in agricultural fields (Manns & Berg, 2014). These correlations, however, were not statically significant after applying Holm’s adjustment. The PERMANOVA did not reveal significant effects of site area or soil related variables on epigeal invertebrate community composition (Fig. 3).

In this study, no evidence was found that epigeal invertebrate richness and abundance is related to the characteristics of urban food production habitats (cultivated area, soil organic content, soil moisture, soil pH or soil productivity as indicated by radish growth). Indeed, there is no evidence in the literature for consistent relationships between epigeal invertebrates and habitat variables in urban cultivated areas. However, this does not mean that the ecosystem services associated with urban food production are insensitive to habitat character, as pollination declines with the proportion of impervious areas in gardens (Bennett and Lovell, 2019).

Not surprisingly, the situation for epigeal invertebrates is different in more complex urban green spaces that include grass, flowers and trees. Thus in California, more diverse gardens displayed greater carabid activity density, but no correlates were found with species richness (Philpott et al., 2019), while in Germany, less isolated, and less intensively managed urban grasslands had greater species richness of carabids and spiders (Buchholz et al., 2018). A UK study did not find ready correlates with invertebrate abundance (Smith et al., 2006a), but found that species richness was sensitive to garden habitat and landscape context (Smith et al., 2006b).

4. Conclusion

A consensus is developing that urban green spaces and gardens may be managed to promote both food production and biodiversity, but there is no evidence as yet of urban food production sites that are too small to be able to draw upon ecosystem services from invertebrates. However, it is possible to imagine urban landscapes that are so sterile that the services of decomposition and pollination could come into question.

Author contribution

SB undertook data analysis; CMDS and LGF co-designed the experiment; CMDS undertook data collection and identification. All co-authors contributed to the writing.

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Table 1. Correlations among variables using Kendall’s Tau-b. Correlation coefficients which were statistically significant at p<0.05, before Holm’s multiple comparison adjustment are shown in bold. No correlations were significant after multiple comparison adjustment. See text for details.

		Tau-b
Soil moisture	Collembola	0.25
	Araneae	0.07
	Coleoptera	0.13
	Carabidae	0.13
	Carabidae species	0.00
	Nebria brevicollis	0.14
	Laemostenus terricola	0.09
	Thalassophilus longicornis	-0.13
	Area	0.04
	Soil productivity	-0.28
	SOC	**0.53**
	Soil pH	-0.12
Soil pH	Collembola	-0.07
	Araneae	-0.11
	Coleoptera	-0.37
	Carabidae	-0.35
	Carabidae species	-0.28
	Nebria brevicollis	**-0.54**
	Laemostenus terricola	-0.03
	Thalassophilus longicornis	-0.23
	Area	-0.34
	Soil productivity	0.19
	SOC	-0.24
SOC	Collembola	0.16
	Araneae	-0.01
	Coleoptera	0.10
SOC	Carabidae	0.15
	Carabidae species	- 0.12
	Nebria brevicollis	0.14
	Laemostenus terricola	-0.05
	Thalassophilus longicornis	-0.15
	Area	-0.10
	Soil productivity	-0.16
Productivity	Collembola	-0.09
	Araneae	-0.05
	Coleoptera	-0.18
	Carabidae	-0.05
	Carabidae species	-0.19
	Nebria brevicollis	-0.16
	Laemostenus terricola	-0.03
	Thalassophilus longicornis	-0.13
	Area	0.09
Area	Collembola	-0.06
	Araneae	0.05
	Coleoptera	0.06
	Carabidae	0.07
	Carabidae species	0.06
	Nebria brevicollis	0.25
	Laemostenus terricola	-0.08
	Thalassophilus longicornis	-0.07

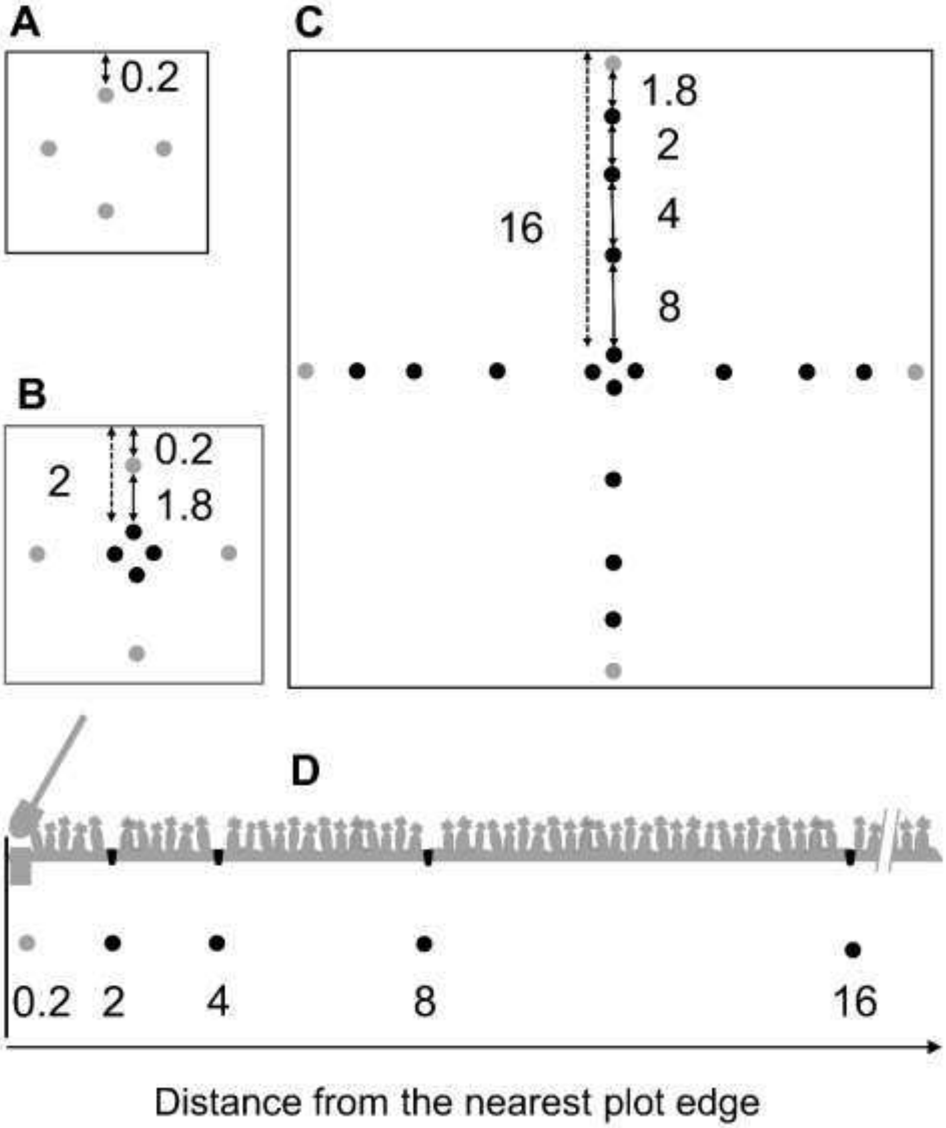

Figure 1. Aerial representation of the sampling design. Continue lines represent distances between traps, and dashed lines represent the distance of the farthest pitfall from the edge.All distances are in meters. A) Small plot with 4 pitfalls; B) Intermediate plot with 8 pitfalls; C) Large plot with 20 pitfalls. D) Soil samples were collected from the first point of each transect.

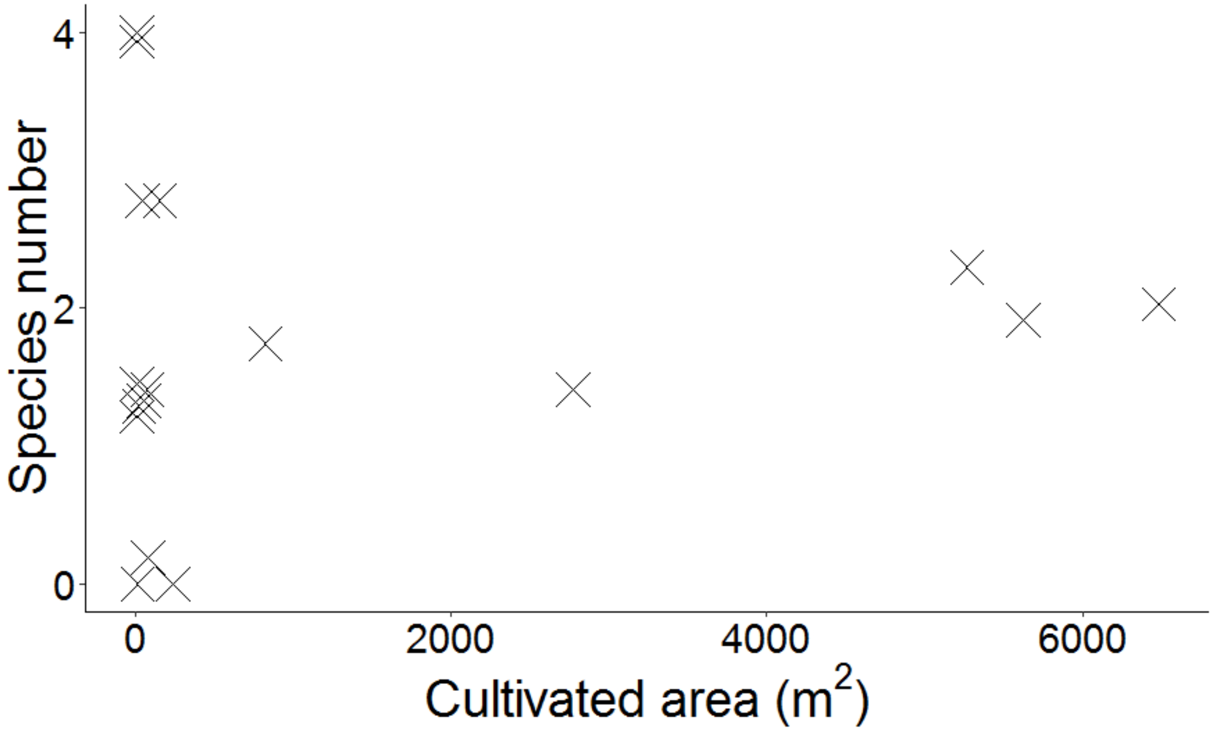

Figure 2a. Total species number of Carabidae at each site across all pitfall traps and the area of the site adjusted by the number of pitfalls in that site.

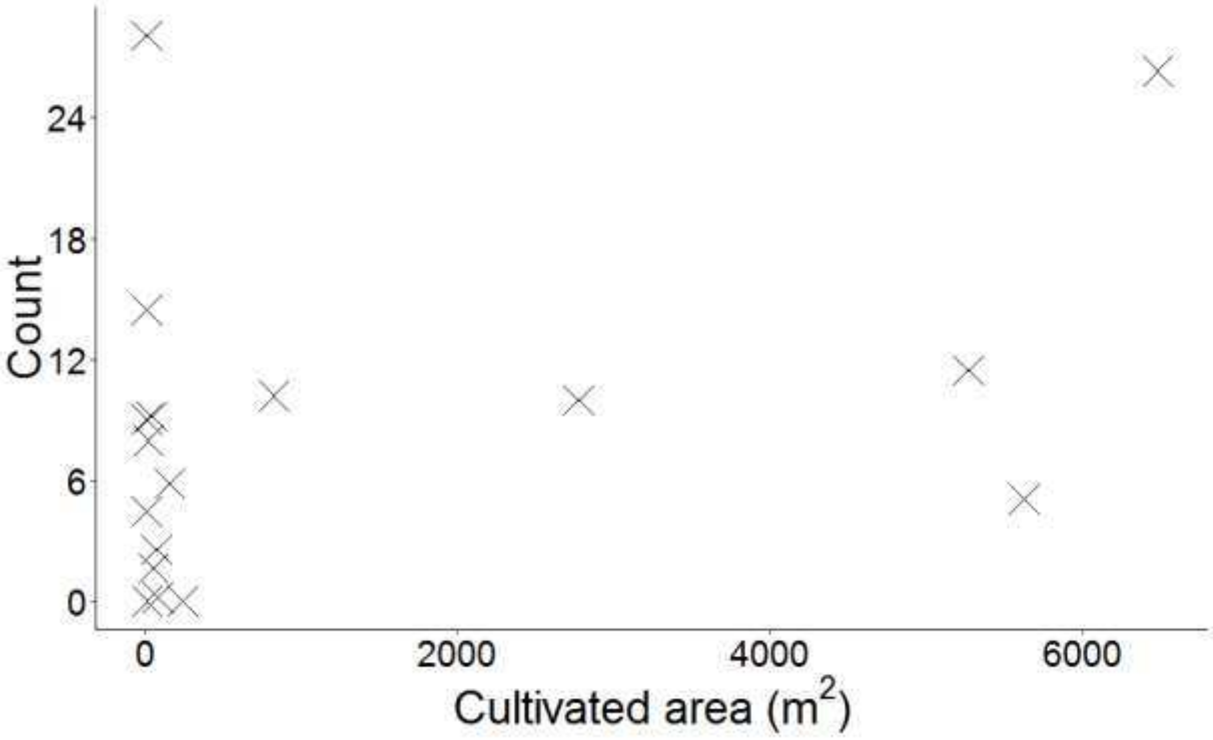

Figure 2b. Total counts of Carabidae at each site across all pitfalls and the area of the site adjusted by the number of pitfalls in that site.

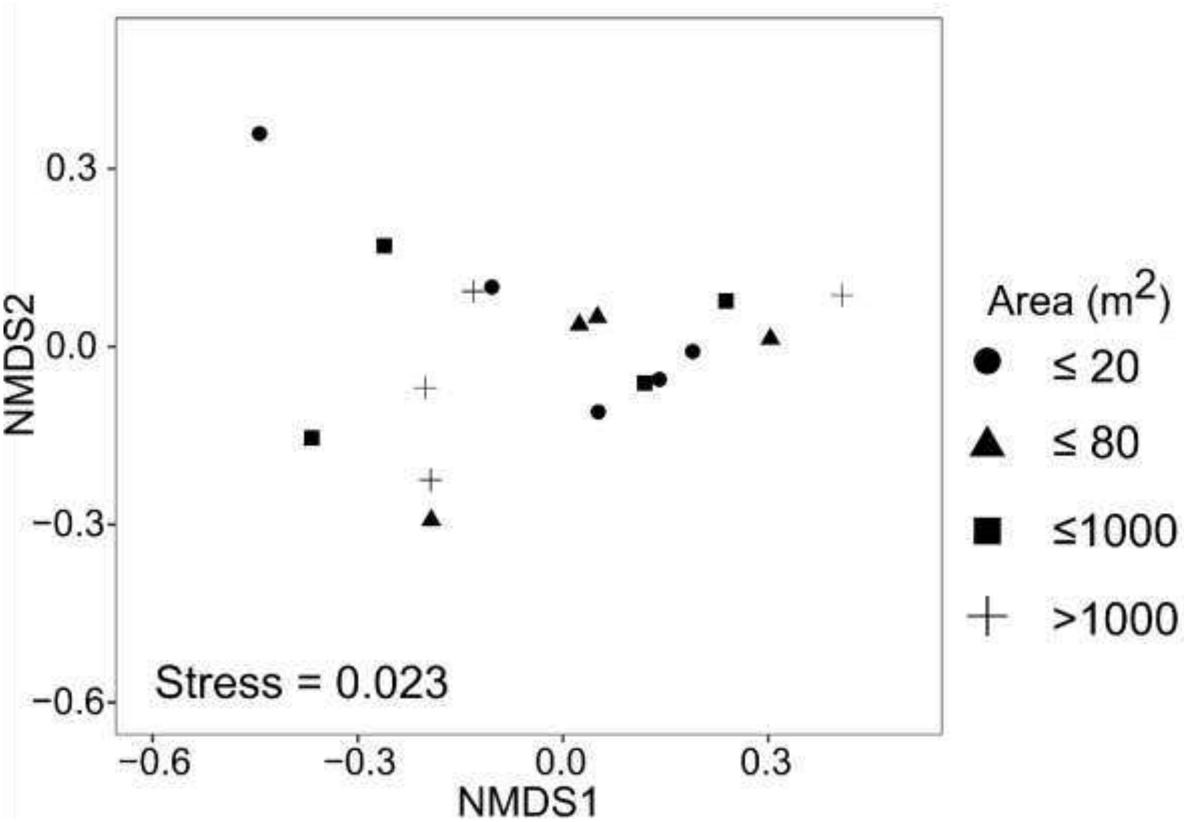

Figure 3. Nonmetric multidimensional scaling (nMDS) plot showing epigeal invertebrate similarity among plots with different cultivated area. Each point represents one of the seventeen sites of the study.

Appendix Table 1. Description of the sites of the study. Sites were randomly selected from the open source database on local food production Urbal.tv.

Site type	Area (m^2)	Pitfalls (N)	Max Slope	Pitfalls installed	Pitfalls retrieved
Community Growing Projects	14.4	4	0%	18/08/2015	01/09/2015
Community Growing Projects	239.7	4	2%	01/09/2015	15/09/2015
Edible Gardens	826	15	6%	11/09/2015	25/09/2015
Council Allotments	6480.5	17	8%	09/09/2015	23/09/2015
Community Growing Projects	80.5	4	0%	19/08/2015	02/09/2015
Council Allotments	157.3	12	0%	27/08/2015	10/09/2015
Council Allotments	43.6	5	4%	10/09/2015	24/09/2015
Council Allotments	11.1	4	8%	09/09/2015	23/09/2015
Council Allotments	5267	16	7%	25/08/2015	08/09/2015
Community Growing Projects	9.6	4	0%	28/08/2015	11/09/2015
Parks containing edible beds	76.2	8	10%	01/09/2015	15/09/2015
Parks containing edible beds	11.4	3	0%	10/09/2015	24/09/2015
Council Allotments	2774.5	16	14%	26/08/2015	09/09/2015
Council Allotments	5624.5	18	1%	26/08/2015	09/09/2015
Edible Gardens	55.8	8	0%	28/08/2015	11/09/2015
Other Allotments	12	4	0%	25/08/2015	08/09/2015

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