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Allotment gardens and parks: Provision of ecosystem services with an emphasis on biodiversity

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ABSTRACT

Urban areas, in particular, present unique challenges for the conservation of ecosystems. Allotment gardens (AGs) are an important greenspace feature of urban landscapes in Europe which have the potential to offer multiple social and bio-physical ecosystem services in addition to food production. This study is an attempt to assess and compare the ecosystem services provided by AGs in Manchester, UK, and Poznań, Poland as well as a comparison to city parks. The surveys included a detailed land cover characterisation and an assessment of cultivated and spontaneous plant species. There are differences in the land use characteristics in the two cities with a preference for vegetable growing and water recycling in Manchester, and a greater number of trees and a higher focus on recreation in Poznań. The consequences of these basic differences are discussed in terms of the ecosystem services that are provided by the two different AG types, and parks. In terms of ecology, there is higher species richness on AGs with a greater proportion of neophytes, which may potentially spread into cities. The species recorded in parks and AGs contained a lot of native characteristics of urban, ruderal plant communities.

Introduction

Ecosystem services is a very attractive research field documented by a rapid increase in the amount of publications during the last decade (Costanza and Kubiszewski, 2012). This approach, providing valid arguments for nature protection, is increasingly being recognised for its importance in government policy and practice (Haines-Young and Potschin, 2008). Interest in services of urban ecosystems (Bolund and Hunhammar, 1999) appeared very soon after the evaluation of world ecosystem services by Costanza et al. (1997).

Urban areas benefit from internal ecosystems which are often threatened. Rapid urbanisation is destroying natural ecosystems and harming the environmental quality of towns (Alberti and Marzluff, 2004). European cities have grown rapidly since 1950 with little attention to the creation of inner city green spaces. This results in areas of the city, of varying affluence and building density, with low green cover, especially trees, and with consequent negative local environmental impacts (Pauleit et al., 2005). Conservation and restoration of ecosystem services in urban areas can reduce the ecological footprints of cities whilst enhancing resilience, health, and quality of life for their inhabitants (Gómez-Baggethun and Barton, 2013).

Urban Allotment Gardens (AGs) have been shown throughout history to be an important urban greenspace that can contribute to the resilience of cities, especially by providing long-term food security in times of energy scarcity (Barthel and Isendahl, 2013). Modern urban agriculture cannot feasibly provide food for all of a city's residents, but it can be a significant source of locally grown food. This was seen in Cuba with an estimated 1 in 10 residents of Havana benefitting from the food grown in the urban gardens (Moskow, 1999). Importantly, AGs provide additional ecosystem services beyond food production such as pollination (Ahrné et al., 2009), local climate regulation, flood protection and an opportunity to socialise in a pleasant environment.

There is currently a need to quantify the range of ecosystem services specifically provided by AGs so that their value as an urban land use can be fully recognised. Quantification of trade-offs among ecosystem services and their interactions with human well-being are among the most pressing areas for research. The general increase in provisioning services over the past century has been achieved at the expense of decreases in regulating and cultural services (Rodriguez et al., 2006).

Generally AGs should represent a 'win-win' situation in this respect because they offer multiple benefits beyond food production and do not incur severe trade-offs in other services as a result

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of their land management practices. Climate change adaptation policies for cities rely heavily on the preservation of, and creation of new, green space. Therefore it is possible that AGs can play a role in this important field. The reduction of food miles associated with locally-grown produce also fits into climate change mitigation policies (Lwasa et al., 2014).

The subject of this study is to present differences between AG ecosystems and their services depending on the manner of use, which varies considerably between nations. In Poland, AGs have existed for over 100 years but they have played a very important role since communist times; in the year 1949 a special act was devoted to 'worker's gardens'. Cities with over 50,000 inhabitants were obliged to establish allotments in every neighbourhood where the proportion of tower block dwellers exceeded 20%. Currently AGs in Poland occupy 40,000 ha and involve about 700,000 users (PZD, 2014). Polish allotment gardeners collectively represent the largest land managers in Poland (Bellows, 2004) and play an important political role as an electorate group.

In the UK, allotment tenancy reached its peak during WWII thanks to the 'Dig for Victory' campaign. During wartime, allotments and gardens produced about 10% of the food consumed in the UK (Crouch and Ward, 1997). After the war, the 'grow to eat' imperative eased and land was required for building new houses and schools. AG numbers declined from nearly 1.5 million in 1950 to 250,000 today (Natural England, 2007). Urban AGs are under threat today because the land is often quite central and highly valued by land developers (Natural England, 2007).

The aim of this study is to estimate differences between ecosystems and the services provided by them on AGs in Poland and the UK, using examples from Poznań and Manchester. The comparative study, using high intensity sampling data at the land use type scale, allows the assessment of two different AG typologies, and a third land use type of urban parks. Ecosystem service quantification work is scarce at the scale of local land use types (De Groot et al., 2010). The study also benefits from a unique investigation into the spontaneous floral diversity of AGs and parks. Ecosystem services are often reliant on the functional traits of the underlying plant communities (De Bello et al., 2010) and flora is a good indication of biodiversity, as it is flora which shapes the structure of organisms at higher trophic levels (Smith et al., 2006). Spontaneous flora is not only a bio-indicator of ecological functions served by the environment but also a record of the synanthropisation process (Borysiak et al., 2014)

This study thus provides a comprehensive snapshot of the ecosystem service provision capacity of an oft-overlooked, but important, urban land use type. The few quantitative studies of community gardens that exist use plant surveys, bee collection and soil testing (Guitart et al., 2012), but no studies characterise the land use on AGs in terms of the spatial bio-physical structure.

Methodology

Study sites

The cities of Manchester (UK) and Poznań (PL) represent differences in the role and management practices of AGs occurring in western and central Europe respectively. Manchester is a large city situated in north-west England. The Manchester city district, which includes the centre of the Greater Manchester conurbation, has a population of over 514,000 (UK statistics, 2014). The Greater Manchester conurbation contains a further nine districts giving a total population of 2.7 million. Poznań is located in the west of Poland. The city population of Poznań is around 550,000, with 1.3 million people in the metropolitan area (CSOP, 2014). The two cities are thus of comparable population; however, Table 1 shows that the two cities differ considerably in terms of AG provision. Seventeen times as much land area is given over to AGs and there is an eightfold increase in the proportion of land cover which is AGs in Poznań. The allotment complexes themselves are also roughly eight times larger in Poznań.

Table 1
Main characteristics of the two study sites (spatial analysis undertaken in ArcGIS and using data from CSOP, 2014).

	Manchester	Poznan
Number of allotment complexes	40	83
District area (ha)	11,564	26,153
Allotments area (ha)	49.1	848.5
Allotment area proportion (%)	0.4	3.2
Mean allotment area (ha)	1.2	10.2

Site visits were undertaken from May to July 2014 to coincide with vegetation being in peak growth and with inflorescences to facilitate identification. Twelve allotment complexes and two parks were visited in Poznań, and nine allotment complexes and eight parks were surveyed in Manchester.

Botanical survey and land use quantification

For all land types, spontaneous plant species growing in the paths, verges, and abandoned areas were identified using Harrap's (2013) 'Wild Flowers' field guide. The plant species were classified as native, or non-native archaeophyte (introduced before 1500) or neophyte (introduced after 1500) (Pyŝek, 1995) using the Atlas of British and Irish Flora (Preston et al., 2002) for Manchester, and Tokarska–Guzik (2005) for Poznań. The Raunkiaer's life-form was also recorded (Zarzycki et al., 2002). The ecology survey of Poznań AGs was undertaken by one author and all the other ecology and land use survey work in both cites was carried out by another author, therefore ecology results are presented separately and comparisons are qualitative.

Satellite images were used within ArcGIS10 to calculate park, allotment and average plot areas. The satellite images are dated 2009 (Manchester) and 2011 (Poznań) and were both taken in summer. Polygons were drawn to approximate the proportion of land surface area which is under tree canopy. This was a fairly straightforward visual task, as the summer images allow for easy identification of both evergreen and deciduous tree canopies. During site walkovers, the following procedures were carried out:

- Trees counted and identified, and height estimated to the nearest metre using tape measure and visual extrapolation.
- Proportion of cultivated ground in each plot estimated as: zero; a third; a half; two thirds; or fully cultivated. An abandoned, overgrown plot represents zero cultivation and a plot with a high apparent level of maintenance (weeding, mowing) on all available land is described as fully cultivated.
- A list of vegetables grown on each allotment complex was compiled
- The number of plots in each allotment complex growing fruit and/or vegetables was noted.
- Area of land used by buildings (sheds, greenhouses, polytunnels) and paved paths/patios estimated by eye and occasionally measured using a tape measure where access was granted. It was noted whether a building was collecting roof rainwater runoff in a container.
- Allotment holders were interviewed to identify additional ecosystem services to the provisioning and regulating services quantified.

Table 2
Summary statistics for study site area.

	Manchester	Poznan	Parks
n	9	12	10
Mean area (m^2)	15,091	39,470	13,072
Median area (m^2)	8072	40,020	9493
Area range (m^2)	1597–51,315	23,961–64,357	3368–37,180

Table 3
Summary statistics for individual allotment plot area.

	Manchester	Poznan
n	497	1 164
Mean area (m^2)	211	369
Median area (m^2)	205	335
Area range (m^2)	107–375	305–560

Due to privacy issues, most allotment surveying was carried out from the paths outside the plots unless invited onto the plots by the owners.

Tables 2 and 3 show the areas of the allotments in this study, selected to cover a wide range of sizes and locations. The mean average allotment complex area sampled in Poznań is smaller than the city mean in Table 1 because larger complexes were not surveyed in their entirety due to time constraints. Data were not normally distributed and are presented in non-parametric box plots, and medians used for comparisons. Natural logarithms of species richness and plot area were used to test species equilibrium theory (Crowe, 1979). Statistics calculated using R v2.15.2.

Ecosystem services assessment

A list of ecosystem services appropriate to urban AGs was selected based on the Common International Classification of Ecosystem Services (CICES) V.4.3 compiled by the European Environmental Agency (Maes et al., 2014). Particular services belonging to one of three groups—Provisioning, Regulating and Cultural services—have been assessed using an approach presented by Burkhard et al. (2012), who used a scale of 0–5 with 0 being no relevant capacity of the land to provide a particular ecosystem service, and 5 being very high relevant capacity. Scoring of ecosystem service provision for the land use types in this study was based on similar land use types in Burkhard et al. (2012) and on the use of personal judgement while taking into account the extensive quantification work undertaken.

Results

Ecology in Manchester AGs and parks

Full lists of spontaneous vegetation and trees in Manchester and vegetables grown are available in the supplementary data. The main findings are summarised in Table 4. The species richness of spontaneous flora is much higher on AGs. Manchester parks have roughly 65% of the species richness of Manchester AGs. Allotment flora belongs to a greater range of families than the park flora. In addition the families found in parks could all be found on AGs with the exception of Asparagaceae (one specimen of *Hyacinthoides non-scripta*). Species richness tends to increase as the area of surveyed plot increases but this relationship is non-linear as it would eventually plateau. The average site richness per hectare varied greatly, with one allotment (Hough End) being small in area but with a large species richness.

Species richness equilibrium theory predicts that the slope of a log–log plot falls between 0.20 and 0.35 as Crowe (1979) found for abandoned urban lots in Chicago. The slope is 0.25 ($R^2 = 0.265$, $p < 0.05$) (Fig. 1) which indicates equilibrium; therefore species richness is a function of area and degree of isolation from other green spaces. Fig. 2 shows that larger proportions of neophytes were to be found in allotments. Widespread species, found in both land types, are dominated by native species and they make up 70% of all the plants recorded.

Table 4
Summary of the ecological survey data.

	Manchester	Poznan	Parks
Overall species richness	87	357	56
Plant families represented	34	70	19
Species unique to the land use[a]	47		17
Plant families unique to the land use	16		2
Overall species richness per hectare	6.4	2.4	4.2
Average site richness	48		25
Tree species richness	28		33
Tree families represented	14		13
Tree species unique to the land use	12		18
Tree families unique to the land use	5		4

[a] Species found only in that land use type in the present study.

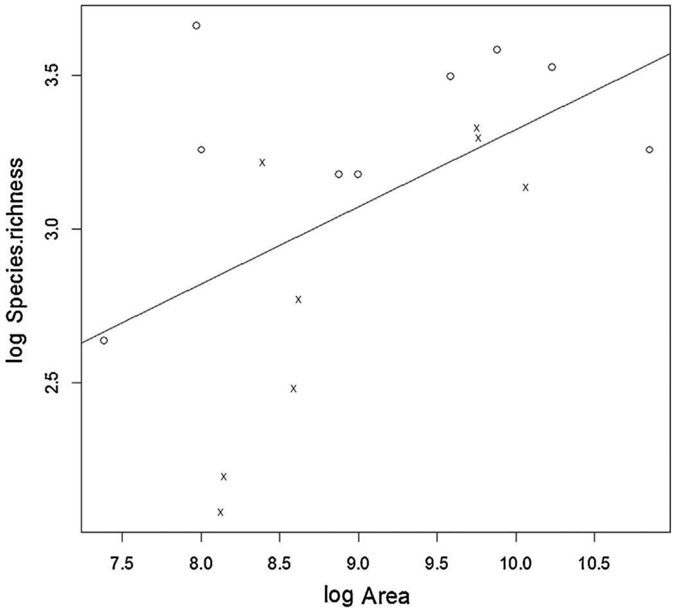

Fig. 1. Log–log plot of species richness against area for Manchester allotments and parks.
O = allotments, X = parks

The dominant UK species tended to be grasses (*Agrostis* sp. and *Lolium multiflorum*) and white clover (*Trifolium repens*) which were found in the paths of allotments. Associated with these ground cover species would be found frequently *Plantago major*, *Rumex obtusifolius*, *Taraxacum* agg. and *Ranunculus repens*. The verges and abandoned plots of allotments were frequently dominated by *Urtica dioica*, *Galium aparine* and *Geranium robertianum*. Of the life forms, 55% were hemicryptophytes, 32% therophytes and the rest were chamaephytes and geophytes, with one nanophanerophyte (*Rubus fruticosus*).

None of the spontaneous species found on Manchester AGs were of any specific ecological interest or classified as endangered or vulnerable on the UK vascular plants red data list (Cheffings and Farrell, 2005). Two of the species are, however, classed as nuisance invasive species: *Impatiens glandulifera* and *Fallopia japonica* (Environment Agency, 2013).

Tree species richness was slightly greater in parks. The species found only on parks included more ornamental trees such as *Cornus* sp., *Ailanthus altissima* and *Robinia pseudoacacia*. Conversely, the

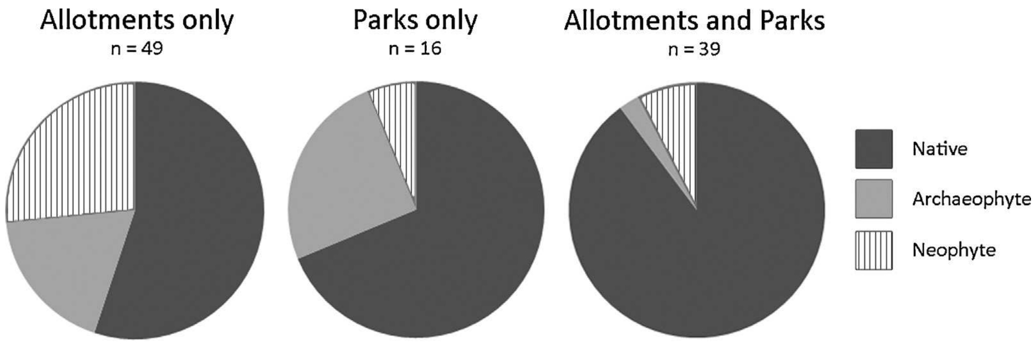

Fig. 2. Pie-charts to show the proportions of native and non-native species found in the two land use types in Manchester.

species found only on AGs included more edible fruit trees such as *Ficus carica*, *Olea europaea* and *Pyrus communis*.

Ecology in Poznań AGs

In Poznań AGs 357 species of vascular plants were found (data not shown). The list included 256 (72%) spontaneophytes and 101 (28%) geographic alien species. These proportions signified a very high level of naturalness of the AG flora. Among the aliens, archaeophytes (59 species, 17%) prevailed over neophytes (42, 12%). Among the life forms, hemicryptophytes (192, 54%) and therophytes (119, 33%) were significantly dominant. Therophytes (49) constituted a high percentage (83%) of archaeophytes (59). The allotment complexes were green urban areas with a high natural value thanks to: 44 (12%) threatened species (hemerophobic) in the Poznań area, 61 (17%) plants at risk in the European Union, 32 (9%) crop wild relatives at risk of decline in European Union countries, 22 (6%) ancient woodland indicators and 58 (16%) species that are bioindicators of the Natura 2000 European Ecological Network habitats.

In Poznań, species richness per hectare is lower than Manchester AGs and parks, despite the much larger species richness in general, due to the very large area covered by AGs.

Provisioning services

One of the main differences between the AGs in the study is how they are used for food production. Fig. 3 shows that all the occupied plots in Manchester are used for growing vegetables. In Poznań only a third of plots, on average, were observed to be growing vegetables and this usually consisted of a vegetable bed with a mean average size of 30 m^2 (less than 10% of the average allotment area). A lot of similarities are apparent in the diversity of vegetables grown in the two countries but there were some notable cultural differences in the amounts of the vegetables grown. For example, kohlrabi and celery are very popular vegetables in Poland but not so common in the UK (and were each only observed growing on one single allotment plot). However, the variety of vegetables grown was larger in Manchester, with more allotment holders experimenting with 'exotic' vegetables like cucamelon and tomatillo from Central America.

More of the AG land is fully cultivated in Poznań than in Manchester (Fig. 4). This is due to a larger proportion of totally abandoned plots and plots with overgrown sections in Manchester. Data on the highest yield available for the vegetable types grown were averaged and multiplied by the area of cultivated land used for growing vegetables to derive estimates of the yield on the allotments (Table 5). It is clear that even though Manchester allotments are smaller in total area, there is more land used for vegetables, resulting in an eightfold yield increase over Poznań allotments. When the land area given over to vegetable cultivation is used to calculate the financial value of the potential yield, gross benefits of £310,900 (£698 per plot) can be expected in Manchester.

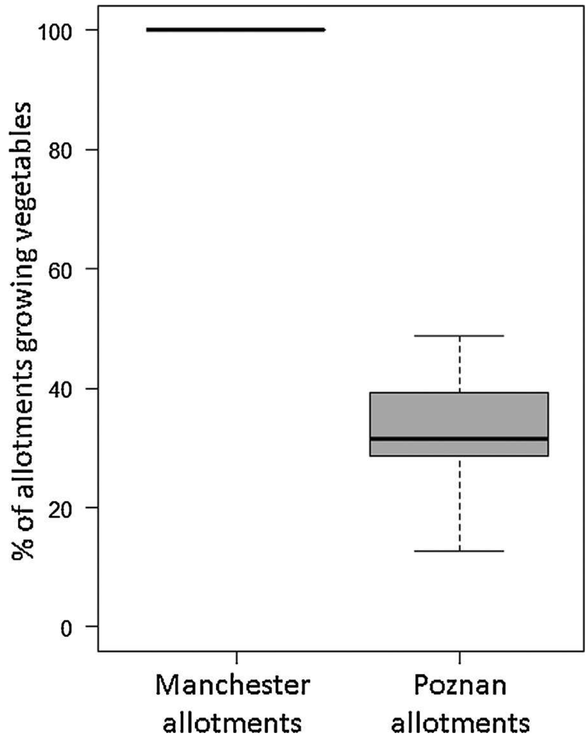

Fig. 3. Proportion of non-abandoned allotment plots which grow vegetables.

Table 5
Summary statistics for allotment food production. Potential yield is based on data from Mobbs (2002) and considering only the vegetables found to grow in the study sites.

	Manchester	Poznan
Area vegetable production (m^2)	89,090	11,070
% of total area	65.6	2.3
% of non-paved area	70.7	2.7
Mean potential yield (t)	615	76
Financial value of yield[a]	£310,900	£38,600
Financial value per allotment	£698	£104

[a]Calculated by average financial productivity per m^2 of £3.49 based on data from 160 allotments in London, UK (Sustain, 2014).

Allotments in Poznań had roughly double the amount of fruit trees than Manchester (Fig. 5). Apricot and peach trees were more common in Poznań and most allotments had at least one apple or cherry tree, even if they were not growing any other fruit or vegetables (data not shown). Walnut trees were very common in Poznań. Apricot and peach trees are seldom found in Manchester,

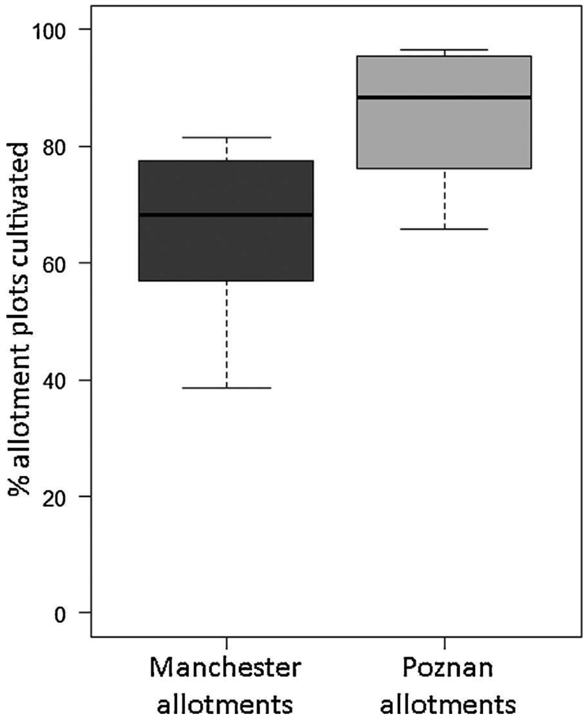

Fig. 4. Degree of land cultivation.

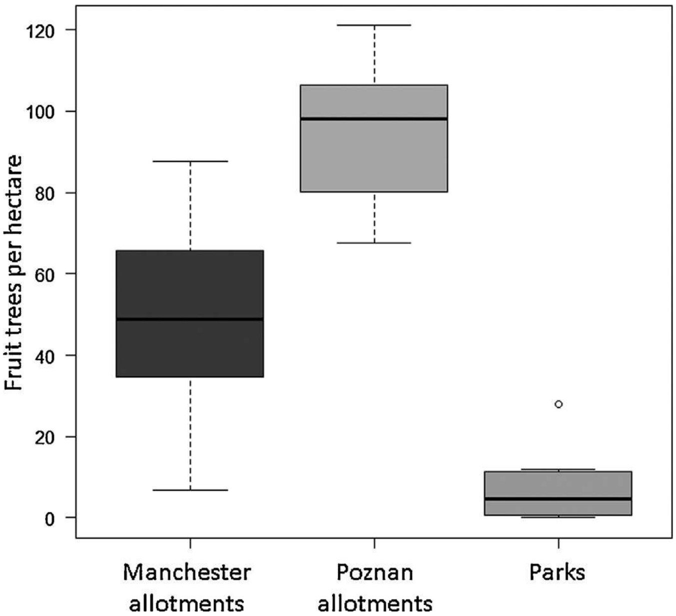

Fig. 5. Number of fruit trees growing per hectare in the three land use types.

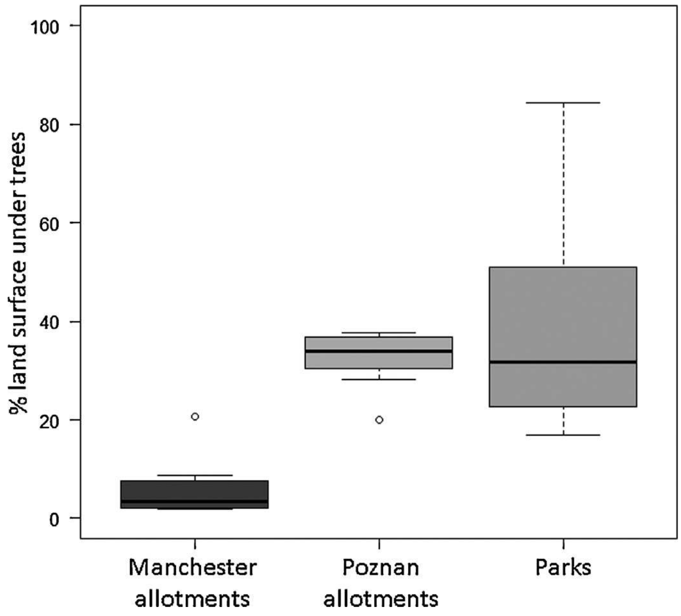

Fig. 6. Proportion of land surface area under tree canopies.

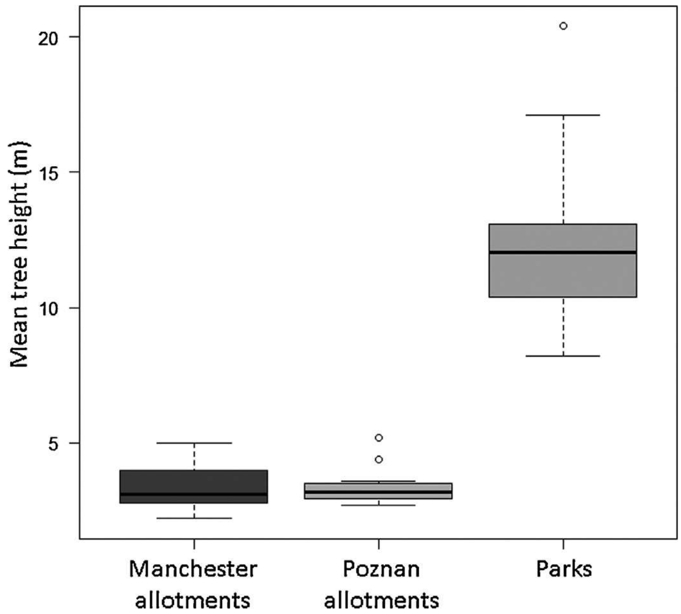

Fig. 7. Mean average tree height.

due to climate and/or cultural differences, but again Manchester experiments with unusual trees such as fig and damson. Fruit trees are occasionally found in public parks and cherry trees dominate, with some apple trees found occasionally.

It was apparent that a number of plots, in both cities, were growing medicinal herbs. These included *Melissa officinalis*, *Mentha* sp., and *Hypericum perforatum* which all have medicinal uses in addition to any culinary uses. Several allotment holders said they regularly drink herbal teas made from some of these herbs for the promotion of well-being. Additionally, chickens were kept on a couple of Manchester allotments, providing food from livestock.

Regulating services

The proportion of trees and the floral diversity are the main elements dividing the level of regulating services between AGs in Poznań and Manchester. The mass ratio hypothesis states that traits of the dominant species by mass in a community exert a key effect on ecosystem processes (Grime, 1998). Traits such as canopy size, growth form, leaf morphology, and tissue chemistry were the four most examined in relation to ecosystem services in the literature (De Bello et al., 2010).

For the two AG types, great differences in tree cover and species composition are observed, with tree cover in Poznań being similar to that of parks (Fig. 6). Poznań AGs have many more trees, of a greater size, and with a higher proportion of evergreen trees (tall cypress hedges and individual conifer trees) than Manchester (Figs. 7–9). Parks have the greatest number of taller trees.

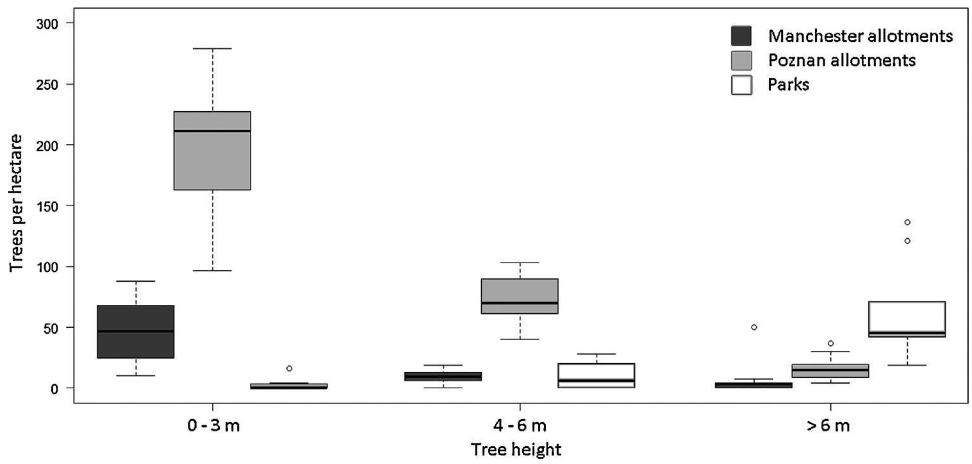

Fig. 8. Number of trees per hectare separated by three tree height brackets.

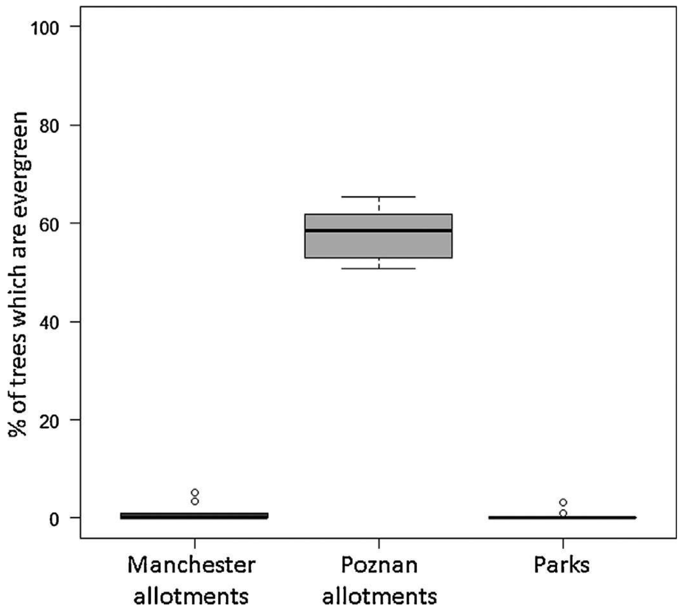

Fig. 9. Percent of trees encountered which are evergreen.

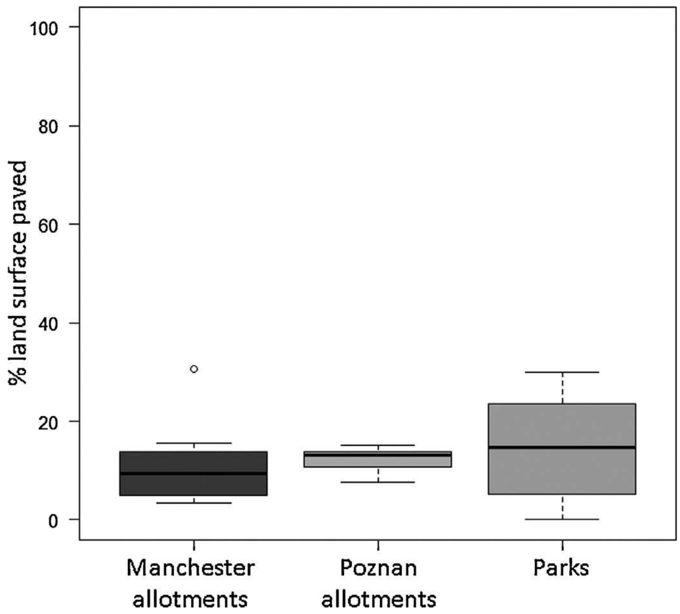

Fig. 10. Percentage land surface area paved (paths/buildings).

The proportion of the land given over to impermeable surfaces (Fig. 10) did not vary considerably between the land types. Poznań AGs had the most buildings but Manchester AGs occasionally had large areas paved for car parks and paths. Parks with high amounts of paved areas usually contained features such as tennis courts and children's playgrounds.

Manchester AG holders are much more likely to capture rainfall runoff from sheds and greenhouses for use in dry periods (Fig. 11). Manchester's average annual rainfall (for the period 1981–2010) is 828.8 mm and that of Poznań is 515 mm. Assuming all the rainfall falling on surfaces connected to barrels is collected, this gives total volumes collected of 1295 m^3 in Manchester and 2239 m^3 in Poznań. The greater number of buildings on Poznań allotments means that the total volume captured is larger; therefore, normalising for total land area gives 12.6 l/m^2 collected in Manchester and 5.1 l/m^2 in Poznań. Ponds were common in both Manchester and Poznań; however, in Poznań the ponds were more for aesthetic purposes than for biodiversity or rainwater storage. The ponds in Manchester allotments were less well manicured and they appear to play a much more ecological role, e.g. providing a habitat for frogs, which help control garden pest populations.

Beehives were also found on two of the Manchester allotments, thus enhancing pollination as an ecosystem service.

Cultural services

AGs can score highly on ecosystem services supporting social life. Social benefits include: social cohesion brought about by bringing together people of different backgrounds with a shared interest in gardening; education about nature and food production; and health benefits by moderate physical activity, especially for elderly people.

Information gained from interviewing AG holders revealed Poznań AGs to provide an important recreation service because they are treated like summer homes, which tenants actually move to in the summer months. Outdoor dining, sunbathing and entertaining friends are common activities. On Manchester AGs, tenants spend much less time on the plots and it is usually to undertake gardening work and chat to other tenants. However, Manchester AGs were often used for education on sustainability and food growing techniques for community groups and schools.

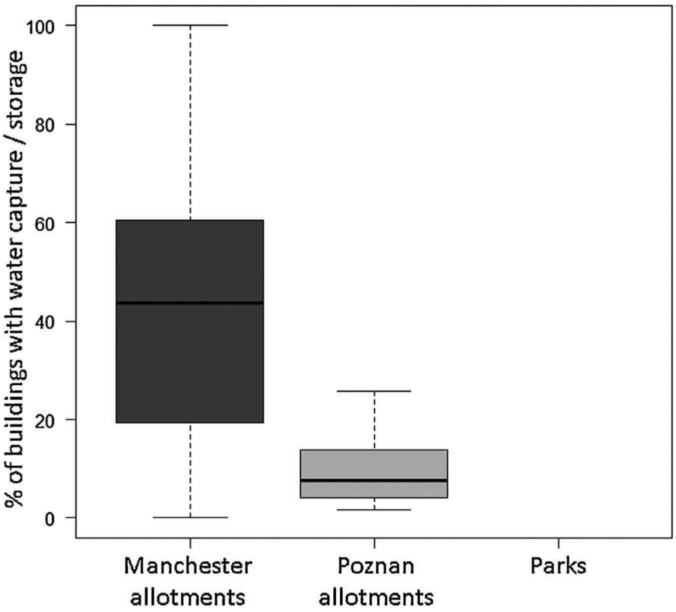

Fig. 11. Percentage of the building infrastructure fitted with the means for capture and storage of rainwater.

Discussion

Ecology

The lower species richness in UK parks is a result of the differences in land management practices between parks and AGs. Parks are mowed frequently and there are a limited number of species which can survive this regular treatment, such as grasses and low-growing plants (*Stellaria media*). Most of the species richness in parks was found in the verges and under benches (personal observation), that escape mowing pressure. Disturbances, such as mowing, prevent the competitive replacement of pioneer colonisers (Haigh, 1980). Management regimes on some UK parks are recognising the potential that parks hold for improving biodiversity, and areas are left unmaintained which consequently become rich in meadow species. Three of the parks in the present study use this strategy, and consequently had high species richness compared to other parks.

The species recorded in Manchester are similar to those of an urban ruderal community surveyed in Birmingham (Haigh, 1980) giving strength to the idea that urban areas have unique and consistent plant community assemblages. The widespread species were mostly native, with the majority of the neophytes appearing on allotments, presumably as a result of introductions, and subsequent escape, of non-natives by allotment gardeners. This is in contrast to the proportion of native plants in domestic gardens. Loram et al. (2008) found only 30% of plants in domestic gardens to be native, but gardens are highly managed spaces with a preference for ornamental species and the removal of native weeds.

On allotments there is a different selection pressure to that of parks—regular digging and upheaval of the soil. This makes allotments highly suitable environments for a wide range of weed species that exhibit one or more of the following traits: long lived seed; rapid growth to flowering stage; ease of germination; self-compatibility; high seed output; good competitors; and vigorous reproduction from fragments (Cousens and Mortimer, 1995). The high proportion of therophytes in both countries was generally found in areas subjected to digging. Ruderal plants are very common in such high disturbance, low stress environments (Grime, 1977). In addition, practices on allotments which enhance crop vegetable production can inadvertently stimulate weed growth e.g. addition of fertilisers, soil warming in winter.

There were differences in the species composition between AG complexes within Manchester indicating the potential influence of the surrounding land-use. The high species richness on Hough End (Manchester) AGs could be explained by its proximity downwind of a large expanse of parks, wasteground and woodland which would provide an external seed input. Management differences on the AGs themselves may also explain some of these inter-allotment differences. An allotment complex with a high number of abandoned plots would have a large internal input of wind and animal-dispersed seeds. The ecological potential of overgrown, abandoned plots (which Fig. 4 shows can be quite significant in terms of land cover) is high, as many of the spontaneous plants were found in these areas, and they can act as wildlife refuges (Natural England, 2007).

There was some evidence on a couple of AGs of culinary species that were likely planted on AGs and have subsequently spread to the paths and verges, such as *Origanum vulgare* and *Melissa officinalis* in Manchester. AGs may provide a pathway for the introduction of novel neophyte invasive species into cities.

Poznań AGs had an impressive species richness. The presence of threatened species is an important result, which highlights the potential of AGs to play a role in plant conservation. It is interesting that the proportion of growth forms represented is highly similar in Manchester and Poznań and this reflects the growth strategies that are suitable for a high disturbance urban land use.

In terms of ecosystem services, some of the spontaneous species recorded are good for pollinator insects, such as *Epilobium angustifolium* and members of the *Geranium* genus. This is not to mention the wide range of vegetables and ornamental flowers grown on AGs, which provide pollen and nectar sources. A study in Germany found over 2000 crop and ornamental species on AGs (BDG, 2008). AGs in Stockholm were found to be functionally connected by foraging bees, but the pollination ecosystem service is weaker in areas strongly influenced by human activity, as measured by impervious surface proportion (Ahrné et al., 2009). Other ecosystem services arising directly from the spontaneous vegetation include wild foods, nutrient regulation and intrinsic value of biodiversity.

The results of this study show that AGs can be highly species-rich environments and may offer a method of food production that does not incur as many trade-offs with biodiversity as other land uses (Rodriguez et al., 2006).

Ecosystem services

Thus far we have discussed the ecosystem services related to plant diversity on AGs. In this section we evaluate the total ecosystem services provided by the different land uses. Table 6 lists the services provided by the AGs and UK parks. Between the two cities there are subtle differences related to different AG management practices. For example, the presence of beehives and livestock on Manchester AGs gave higher scores in the pollination and livestock categories. In terms of cultural services, parks are highly communal spaces that can be used by many people. AGs tend to be fenced off and strictly for the use of tenants only, due to issues with vandalism and theft. This limits the impact of AGs in terms of providing large numbers of city residents with access to greenspace. However, a recent trend in the UK is to create community AGs that can be used by large groups of people such as schools.

Parks generally lack the provisioning services found on AGs but give important benefits related to trees. Evergreen trees in particular, are highly beneficial because they potentially provide multiple ecosystem services, related to leaf area index, year-round. A review of 115 tree research papers found carbon storage, air quality improvement, microclimate modification and energy

Table 6
Matrix for the assessment of the different land cover types' capacities to provide ecosystem services. The assessment scale covers 0 = no relevant capacity, 1 = low relevant capacity, 2 = relevant capacity, 3 = medium relevant capacity, 4 = high relevant capacity and 5 = very high relevant capacity.

Ecosystem service	Manchester	Poznan	Park
Provisioning services Σ	20	18	6
Crops	5	5	1
Livestock	2	1	0
Fodder	4	4	0
Wild food	2	1	1
Wood fuel	1	2	1
Genetic resources	4	3	2
Medicine	2	2	1
Regulating services Σ	19	22	22
Local climate regulation	3	4	4
Global climate regulation	1	2	2
Flood protection	1	1	1
Ground water recharge	2	2	2
Air quality regulation	2	3	3
Erosion regulation	2	2	2
Nutrient regulation	1	1	1
Water purification	1	1	1
Pollination	4	3	2
Noise reduction	2	3	4
Cultural services Σ	18	17	18
Recreation	3	4	5
Intrinsic value of biodiversity	2	2	1
Aesthetic value	3	3	4
Social relations	3	3	3
Knowledge systems and education	4	2	2
Cultural heritage	3	3	3
Total	57	57	46

savings (from cooling) to be the four most commonly reported, with noise reduction, biodiversity/habitat creation and flood amelioration being lesser reported ones (Roy et al., 2012). Trees are also better for increasing the species richness at higher trophic levels of ecosystems i.e. invertebrates (Smith et al., 2006). In this respect, Poznań AGs outperform Manchester AGs in these ecosystem services because non-edible trees are generally absent, or of a small size, on Manchester allotments in order to reduce shade and maximise vegetable yield. This has consequent differences in the regulating services provided by the land uses.

AG land use tends to be a highly heterogeneous mosaic of different vegetation types with some 'wild' areas. Overgrown, abandoned land was very common on Manchester AGs. This provides opportunities such as foraging for wild foods (wild blackberries were common) and is a stark contrast to the intensive monoculture of modern agricultural practices. Industrial crop production has been found to be at odds with regulating services at the European regional scale (Maes et al., 2012) but AGs offer these regulating services, albeit at a smaller scale. For example, topsoils of UK allotments were found to be higher in soil organic carbon and total nitrogen and lower in bulk density than conventional agricultural fields (Edmondson et al., 2014). Small scale urban food production can occur without the soil degradation common to conventional agriculture thus preserving regulating ecosystem services such as carbon storage, nutrient cycling, water purification and climate regulation (Edmondson et al., 2014).

Support of pollinators is increasingly important given the reported decline of pollinators such as bees, and the potentially disastrous consequences this will have upon crops (Goulson et al., 2008). AGs in Sweden were found to be important alternatives to rural habitats for bee populations, albeit with variable abundance data for certain species. Management practices, such as the presence of native flowers, strongly affect abundance and species composition (Ahrné et al., 2009). Allotment tenants are increasingly aware of the benefits of attracting pollinator insects and the past few years has seen more high-nectar flowers, such as *Phacelia tanacetifolia* and *Trifolium pratensis*, being planted alongside vegetables. Some allotment holders grow heritage and heirloom varieties of vegetables, as opposed to engineered hybrids, and this can be an invaluable provisioning ecosystem service by imparting genetic diversity (Natural England, 2007).

It is worth noting that many of the additional ecosystem services beyond food production, provided by AGs, have spatial impacts beyond the confines of the gardens. Local climate regulation, flood protection and air quality regulation will especially benefit a large number of local residents in cities at the neighbourhood scale.

The social aspects of urban vegetation are often overlooked in research (Roy et al., 2012). A study in the Netherlands suggested that elderly allotment holders enjoy greater health than their neighbours who do not own an allotment due to the maintenance of an active lifestyle (Van den Berg et al., 2010). AGs act as a collective social-ecological memory-preserving site (Barthel et al., 2010) which is important in cities because urban dwellers who do not experience nature first-hand early and regularly are less likely to be motivated to become stewards of ecosystem services later (Rosenzweig, 2003).

Urban AG popularity tends to increase in times of hardship, such as during wartime, by providing food security. A recent example is the reduction of Soviet aid and trade in Cuba prompting the explosion of urban gardens in Havana (Moskow, 1999). Climate change may pose a new form of threat to food security by increasing the frequency of extreme weather events. There is a potential therefore for AGs, and their regulating ecosystem services, to help with climate change adaptation and mitigation (Lwasa et al., 2014).

AGs in the UK are recognised by the government as valuable community spaces with multiple benefits, and there are legal and policy safeguards in place to ensure local authorities cannot sell or appropriate AGs without the consent of the Secretary of State (DCLG, 2014). In order to meet the criteria of section 8 of the Allotments Act 1925, the council must make adequate provision for displaced plot holders. Nonetheless, the National Allotment Society of the UK is receiving increasing numbers of calls from worried tenants who feel that the land is under threat from development (NAS, 2014). A problem could be that allotments fail to conform to the ideal of private, individualised space and conventional discourses on municipal recreation and leisure (Crouch and Ward, 1997; De Silvey, 2003). Solutions are to recognise the importance of AGs as a beneficial urban land use type within local government policies and to promote their benefits to citizens. Benefits, as this paper has shown, go beyond concepts of community food security and put AGs firmly within discussions on sustainable development, biodiversity and social cohesion.

Conclusion

AGs provide a wide range of ecosystem services in urban areas. Services related to pollination, food provision, biodiversity and recreation rank very highly on AGs. In particular they provide a number of ecosystem services that have great importance in cities due to the high density of residents, traffic and impervious built surfaces. These include local climate regulation, noise reduction, air filtering and recreation. They offer local authorities the potential to intervene in tricky to manage ecosystem services such as pollination and soil formation by simply providing a source area with no need for advanced technologies (Bernaciak, 2012). They also offer multiple ecosystem services with fewer trade-offs than other agricultural land uses (Rodriguez et al., 2006).

The AGs in this study scored highly on several provisioning and regulating services as a result of the type, diversity and distribution of the vegetation. Cultural services were also highly apparent as AGs offer urban residents a chance to socialise, share knowledge, and connect with nature. Differences between the two AG typologies were noted, with fewer trees on Manchester allotments due to a cultural preference for vegetable growing. Urban parks, in comparison to AGs, can be enjoyed by a greater number of city residents and have more, and taller, trees with associated ecosystem services. Parks, however, lack the species richness of AGs and also do not score well within provisioning ecosystem services.

Some suggestions for improvements on AGs include: Strategic planting of trees on Manchester allotments to provide shade for a future warmer climate; increase the amount of water capture from impervious roof surfaces for irrigation uses; promotion of holistic, organic gardening practices; install beehives and non-ornamental ponds; and increase public interaction on allotments.

The results of this study suggest that there may be a need for more formal recognition of ecosystem service provision by AGs in local government policy in the European Union. Allotment tenants are local stewards of urban green space and thus serve an important role in protection of biodiversity and climate change adaptation, which are commonly-cited goals of local government. Locally-managed, non-protected green spaces can spatially dominate cities compared to protected ones such as nature reserves and greenbelt. Green areas managed by local user groups may play an increasingly critical role in the future functioning and resilience of urban ecosystems (Colding et al., 2006).

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Appendix A. Supplementary data

Supplementary material related to this article can be found, in the online version, at doi: 10.1016 j^{-1}.ufug.2015.07.007.

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