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Sustainability, Resilience, and the Contribution of Private Urban Gardens

Fabricio Chicca[1], Emilio Garcia[2], Brenda Vale[1]

[1]School of Architecture, Victoria University of Wellington, Wellington, New Zealand

[2]School of Architecture and Planning, University of Auckland, Auckland, New Zealand

Email address:

fabricio.chiccca@vuw.ac.nz (Fabricio Chicca)

Abstract: One of the few subjects that still enjoys great support from built environment professionals, governments and communities is the importance that green areas have for cities. However, the green space available is only a portion of the entire green infrastructure. Private gardens are also important contributors to green infrastructure. This article explores the role of private green areas and their long-term contribution to cities, not just in terms of resource and energy use (sustainability) but to concerning the capacity of those living in cities to adapt to internal and external pressures (resilience). Therefore the question that arises from this research is: how can private gardens be valuable for the sustainability and resilience of cities? The methodology is essentially qualitative. It uses logical argumentation inductive and deductive methods. The value and contribution of private gardens to cities are presented through a literature review including a brief history of private gardens and their role in contemporary life. The article uses New Zealand as a case study to analyse the role, contribution and potential of private gardens in terms of resilience and sustainability. The final aim is to provoke a discussion around the present and future use of private green areas.

Keywords: Private Gardens, Sustainability, Resilience

1. Introduction

One of the few subjects that still enjoys great support from built environment professionals, governments and communities is the importance that green areas have for cities [19]. Greener cities are not only aesthetically pleasing but also contribute to creating healthier environments by buffering pollution and counteracting the impact of the urban heat island effect [21]. For this reason, the governments and city councils that are concerned about the urban environment have made efforts to conserve, update and even create new public green areas in cities. As an example, in Wellington, New Zealand the city council has included the importance of keeping greenery within the city in its plan *Wellington towards 2040: Smart Capital* [92]. However, council-provided green space is only a portion of the entire green infrastructure of the city. Private gardens are also important contributors to green infrastructure, which is defined as the areas not covered by impervious surfaces, like streets or the roofs of buildings [8]. In urban low-density built environments a great percentage of total city green space is still linked to private gardens. However, the existence of these green private areas is vulnerable since they are not always subject to the policies that preserve and protect public green areas. Moreover, green areas in private gardens are largely dependent on private interests and are also subject to changes in planning policies such as the promotion of infill housing, meaning private green areas are under threat in the transformation of built environments into compact, smart cities.

In the last twenty years, there has been progressive discussion of making the built environment, particularly urban areas, more compact in order to reach the goals of sustainability [50, 51, 70]. The discussion has centred on people living close to work in denser settlements to avoid the time and energy associated with the daily commute [69]. The balance between built and non-built areas and their land uses in this future, compact and denser cities have also been discussed [53], leading to the conclusion that careful planning is required if green space is to be preserved. Private

green space, in particular, is often under threat in the move to more compact and higher-density settlements through densification [71]. This article explores the private garden through separate examinations of its aspects to suggest what the role of private, urban green spaces might be in the future, especially if that future is a post-oil one. Should private gardens be encouraged, or should the green public realm be more important than the private in the cities of the future?

2. Green Space Ratios

The provision of accessible green space becomes more important if private gardens are to be sacrificed to increase the density of cities. However, it seems there is no agreement over how green space in urban areas should be measured so standards can be set. The following table sets out standards from various countries and the references.

Table 1. Measures of green space in urban areas (adapted from Isowoyo, 2014).

Assessment	Standard and reference
Maximum distance to nearby green space	280-300 m (English Nature) [41, 43] 500 m (Aarhus, Denmark) 400 m (Zurich, Switzerland) [15]
Walking time to nearby green space (accessibility)	15 minutes (Europe) [6] 10-15 minutes (Switzerland) [15]
Provision per 1,000 population	- 1 ha [41, 43] - 0.765 ha [45]
Green space allocation for each urban citizen (Green space per capita)	9 m^2 (WHO) [82] 200 m^2 (Wellington, NZ) [82] 104 m^2 (Europe) [58] 800 m^2 (France) [58] 80 m^2 (Canberra, Australia) [82] 10 m^2 [43] 8 m^2 (Zurich, Switzerland) [15] 38 m^2 (India)* [82] 3 m^2 (Hong Kong) [82] 27.3 m^2 (China)** [82] 1.9 m^2 (Malaysia) [75]*** 5.0 m^2 (Japan) [75] *** 11.5 m^2 (Lancashire, England) [75] *** 60 m^2 (USA) [75] *** 1.5 m^2 (Jakarta, Indonesia) [75] *** 17.3 m^2 (Makassar, Indonesia) [45]***
Trees/crown coverage	27% (USA) (Singh et al., 2010) 18.6% (European average) [82] and 1.5 to 62% [72] 27.85% (India)* [82] 1.81% (Hong Kong) [82] 32.54% (China) [82]
Number of Trees per resident	23 (China) [82]

* Average measure of 2 main regions: Delhi and Chandigarh
** Average measure of 2 main cities: Nanjing and Wuhan
*** Regulated value.

Table 1 shows little agreement over how much green space/person should be supplied, with values ranging from 5.0m^2/person in Japan to 200m^2/person in Wellington, New Zealand. Obviously, these values have a cultural component. Moreover, standards like these ignore accessibility, as small, frequently occurring green areas are far more accessible than large parks on the edges of built-up urban areas. The definition of accessible green areas that are free to the public is essential to further this debate [66] because it affects the perception of their usefulness. One observation is that the measures of green areas ignore the presence and contribution of private green areas, especially in such issues as tree cover and the number of trees per resident.

3. Inherent Value of Private Gardens

The supply of accessible public green areas rather than private ones could address problems such as walkability, as privatised green space may create long detours for pedestrians. An urban fabric with high levels of privatized green areas often reflects differences in income in the built form of the city, with the poor being disadvantaged by having to walk long distances around the edges of gated communities [17]. At the same time, this protected private green space can have ecological benefits within the urban fabric, through the creation of habitats and, by being in the collective private hands of the well-off, this could even be legislated for this to happen. Although suburban gardens may look far too tidy to be good ecological habitats, they can still have benefits. Research in Westchester City North of New York found that urban landscapes hold relatively diverse and viable bee communities in suburban gardens [30]. In this instance, the suburban gardens are forming a network that allows the bees to travel to and from a base to gather nectar. This is a good example of the mismatch between natural and political boundaries, a factor that reinforces the inherent

ecological value of private gardens that is not always contemplated in measures of green space.

Private gardens can also be used for human food production within urban areas. In the European urban past and often in modern Asian cities, private green space was for growing food, especially in areas not visible from the street. In the first half of the 20th century most families in New Zealand, for example, would once have enjoyed vegetables and fruit grown at home and vegetable growing formed part of the school curriculum [9]. Now, despite money and time being spent on landscaping many of these garden areas are no more than the view from the window and are seldom entered [54, 63]. However, in times of stress, such spaces can be put to productive use, as will other green spaces within the urban fabric. In WWII 10% of all food produced in the UK was grown on allotments established on hitherto unproductive land, and in private gardens [22], whilst earlier in the USA 40% of the American supply of vegetables was grown in Victorian gardens [61]. This suggests that the presence of private gardens within the urban fabric does have an effect on opportunities to produce rather than buy vegetables and that this space does not have to be private. Urban green space, whether public or private, has also been associated with 'health' through being equated with the 'lungs' of the city [65].

The current debate about cities is focused on the promotion of compact and smart-built environments. These are presumed to be more sustainable when it comes to dealing with more people living within cities, a situation that these ideas are also helping to aggravate. The hypothesis is that increasing the built density within cities should help to preserve the green areas in the hinterland without destroying the remaining green spots within the city. Moreover, the clustering of people in cities should encourage walkability, more use of public transport, and business development and investments [7]. This is also the foundation of the smart city concept as the "smart" part is linked to the implementation of technological advances to collect and use data to increase the efficiency of city services [32]. This includes the development of alternative ways of transportation and communication between people using digital advances. However, the compaction of the built environment is hard to achieve without losing the quantity and quality of green areas in the form of private gardens. Some of the inherent values of private gardens are easily jeopardized if their sizes are reduced dramatically or if they are overshadowed by tall buildings [86]. Accepting the importance of the international debate around the compaction and densification of cities, it is important to develop an understanding of what is at stake when talking about private gardens in cities and whether these need to be retained, given that private urban gardens have their history.

3.1. The Urban Garden: A Brief History

A 2005 study suggests that a garden is essentially an enclosed outdoor space, dating the first such enclosure to 10,000 BC. However, a 1956 study sees large cultural differences in what happens within such a private enclosure, from the Chinese evocation of a favourite landscape to the English ideal of a sheltered place for growing perfect flowers [28]. The very act of enclosure also suggests that the garden is exclusive and for private use, the very opposite of the shared 'wealth' of the commons. Such private green space has long been a part of urban development. An 1841 study describes such a garden in the 18th century behind the house and shop of Gabriel Varden whilst bemoaning the loss of such spaces and the near contact with nature in his own 19th-century London [24]. Similar small urban gardens would be found to the rear of 17th and 18th-century merchants' houses in Amsterdam, even though the land was at a premium [57]. The amount of land surrounding any dwelling is primarily a reflection of wealth, as was its use. Consequently, someone poor would have a small area of land but would probably use this for growing food, whereas wealth meant the garden was seen as a place for recreation. In Roman times when the poor lived in insulae (apartments) and the rich in villas [88], the richer the person, the more private land they had for a garden and the less they had to use this land for growing food. This is the model and the meaning that private gardens have inherited from the past and that can be seen now in rich countries and in the gated communities for the wealthy found in developing countries.

In 19th-century UK cities the private garden in the overcrowded and unhealthy cities of the industrial revolution was not an aid to health; improved health was achieved through new systems of sanitation and water supply. Rather the private garden and 'garden cities' and garden suburbs' were a reaction to rows of the new sanitary by-law housing where, *"...in the majority of cases nature has been completely dethroned"* [14]. At first green space was provided as groups of allotments at a distance from the housing for growing food and flowers, similar to the 'kleingarten' or Schreber Gardens [80] found on the fringes of many German cities, often with a small cottage where city dwellers could camp at the weekend while gardening [40]. Later, it was thought more convenient for family life if the garden was around the house, even though this could raise the rent through an adjustment to the rates [14]. The gardens for the industrial village of Bournville in Birmingham were designed to keep the worker, who had been indoors all day, fit and away from the pub [44], with space to grow flowers on the front, a vegetable garden behind and three rows of fruit trees at the end [3, 14].

With the advent of the car the streets were no longer safe places for children to play and often space for play took over from space for vegetables in the garden. Moreover, gardens became subject to fashion, such as the replacement of the once fashionable "Hybrid Tea" rose, now considered vulgar, with older shrub roses with their attendant mildew [76]. In the developed world the private garden has become almost as much a status symbol as the private car and people alter their garden almost in the way they would alter their kitchen, as part of a display of wealth. Such a movement has now culminated with television series based around the idea of the instant garden make-over, with the garden being a reflection

of the house and its owner as much as a car or clothing. This is suggesting that nature can be designed, something that usually comes with an expensive price tag, rather than seeing the garden as a place where the householder comes to understand that nature is always evolving and that gardening is about moving with this evolution, whilst nudging it towards the desired outcomes, whether fruit or flowers.

3.2. Private Gardens in Contemporary Life

In recent decades, there has been an increase in the number of low-density subdivisions in city fringes in countries that have very different cultural backgrounds and urban design histories: in Spain [48], Egypt [5], Turkey [4], and the USA [12]. Another common thread is that the residents of these areas no longer use their gardens to grow food. Although, in some parts of the world, some families still rely on their backyards for food [18]. The change in the demands of everyday living has impacted the use and role of private gardens. At present, it is understandable that not many people spend much time in their gardens, partly through the need to work to pay for them and because children are now involved in more formal activities outside the home than before [46]. This is in marked contrast to how gardens used to be used. A study of how people used to live in the 1930s and 1940s in New Zealand, found that all households grew vegetables, with the father doing most of the work, though often the children (the interviewees) had to help. Children played not in the garden but in public spaces, such as the street [63]. Playing soccer on the streets was a very common activity in all South American cities and was where many great soccer players developed, especially in suburbs, where there was less traffic and some of the streets were not even paved. Here it was normal to find children playing soccer from siesta time until late in the evening.

The garden is still valued as something to be looked at and the typological changes in houses post WWII, certainly in New Zealand, looked at creating clearer links between the interior of the house and the garden. The contemporary aim is to create an indoor/outdoor flow, with the garden seen as an outdoor room of the house, or even a series of connected rooms [11]. For the rich, this link between house and garden goes back to the Arts and Crafts country houses of the UK. "It is upon the right relation of the garden to the house that its value and the enjoyment that is to be derived from it will largely depend. The connection must be intimate, and the access not only convenient but inviting" [52]. The garden might also be subdivided with each section linked to the next, creating a series of 'rooms', just as the house might be planned [52]. This connection between the house and garden was emphasised in the development of the modernist house, where the garden was set out to respond to the architecture, so that at High and Over (1931, designed by Aymas Connell) the canted plan is reflected in the stepped triangular terraces at the rear of the house [87]. When Shepheard stated, "…the modern garden should find its inspiration in the contemporary scene…" he was stressing the importance of the garden and house being viewed as a single design entity

[81]. This view, that the garden is now a designed space, rather than one that serves a practical purpose, pervades many books on garden design [11, 82, 83, 78]. If with densification, this garden becomes even smaller, then the bond between it and the house would be potentially stronger, so "Nature and architecture are fused" [11] but at the expense of losing the productive potential of private gardens. This suggests that the shift in the use of private gardens has a strong cultural component and one that seems to play with the aspirations of the middle class.

4. The Socio-Economic Meaning of Modern Urban Gardens

As suggested above, because households are better off today the garden is an extension of the house and a place of leisure, and no longer the place for the production of food. The private garden is also more important in individualistic cultures where entertaining occurs in private space (the house and garden) than in collectivist cultures, where public spaces (streets, squares and gardens) and popular meeting points (pubs, restaurants, and coffee shops) are used [23]. However, development and its accompanying increase in wealth [89] tend towards individualism at the expense of collectivism, and in parts of the world, this has led to an uneven distribution of green space within the city. As shown in table 1, the Food and Agriculture Organization (FAO) of the United Nations recommends 9m² per capita of green area and many urban regions struggle to achieve the minimum required [29]. Furthermore, some areas that are included in an inventory of green spaces are inadequate and virtually useless. These are often denuded of trees or other plantings, being essentially unoccupied land, probably waiting for further development [67]. Trees are also not always integrated into urban planning and design in less developed countries [29]. In cities like Hanoi, where people already use public space such as sidewalks in intensive and multiple ways, with activities changing from day to night, public green space has been dramatically reduced, and what there is very well used. This factor may make cities look alive but this enhanced density of people happens at the cost of reducing usable space in homes, private gardens, and public green areas within the city [60].

As well as the depletion of green areas, the unequal distribution of green space within cities is also an important factor. In Sydney, a study has pointed out the relationship between green areas (either public or private) and the social level [64]. Ideally, access to green areas should be shared equally among the inhabitants of any urban area but at present, it is the wealthy parts of cities that are more leafy and green (and more individualistic) and often the areas of the poorest people have no such attributes (but are more collectivist). A great number of cities have had their expansion based on private developments and since ancient Rome, the regions around the city that are characterized by their considerable green areas have been taken by the highest

classes for their use, with some of these areas kept just for relaxation [42].

Segregation of social class and green environments is probably more visible in developing countries. Private properties are generally larger than their poorer counterparts and tend to have larger private green areas, with the poorer parts of cities frequently suffering from a lack of green areas [55]. Although research has identified the importance of green areas, in countries with a significant social gap, like Brazil, there tends to be a lack of spaces for leisure in areas with low average income [67]. Also, researchers found people in the UK living in deprived suburbs reported poorer accessibility to green areas [10]. They also saw a strong relationship between lower social levels and the lack of green areas in some areas of the Netherlands and Bavaria. As result, access to green areas may become aspirational among the lower urban classes. This is a potential problem with densification. With the loss of the private gardens it could be the poor who have poor access to the available public green areas. The wealthier are more likely to have some form of private open space, however, small. These facts highlight the importance of green areas in illustrating the inequality of opportunities in cities, despite the fact researchers have shown that contact with quality urban green areas has a positive effect on the user [16].

There are different ways to classify modern green areas. Probably the most common differentiation is spaces for recreation and leisure, spaces for environmental conservation, and areas for educational purposes (Morero et al., 2007). Although green areas for food and energy production are not commonly acknowledged in this context, they are perhaps fundamental in reducing social inequality. Obviously, it is not possible for all food to be grown within a city but the ability to grow at least some food, as discussed above, has benefits, not least the visible connection between food and where it comes from. This maintains the importance of rural areas to the city as a whole and should be taken into account during any development process where sustainability is the goal [74]. The direct benefits are also obvious. When reformers like Cadbury were advocating the private garden as part of the natural balance between indoor and work and outdoor recreation, the economic benefits of having such a garden were calculated in 1901 as almost 2 shillings/week [44] when in the same year a labourer might be earning 19-22 shillings/week [78], making 9% of total income. Thus, with densification and the loss of private gardens the poor could also be affected economically.

5. Private Gardens and Food Security: The Case of New Zealand

The idea of increasing the food security of a society by improving and exploiting the green areas of their urban systems, whether public or private, has been promoted as a strategy for decreasing the vulnerability of a community to food shortages. One area of modern research with implications for densification is the role that private gardens can play in enhancing the food security of a city. Particularly during times of privation, such as during drought or war, backyard food production has and could have an important role in supplying food. For example, private gardens can be understood as productive landscapes where a family can adapt to potential food shortages by returning to growing food at home [59].

This could be important when considering the presence of private gardens at the bigger scale of the urban landscape and could challenge urban paradigms of compactly built environments. However, it is still difficult to find data with which to assess the precise contribution of private gardens to urban food production in the past, as well as for defining and mapping the boundaries of these productive private gardens. Commonly the garden at the front of the house has always been for display and that at the back for production [62]. Researchers have stated the difficulty in gathering data about private urban food production in Oceania [59]. Despite this, it is still possible to infer and establish some relationships from the existing records.

New Zealand is a good example of the value that private gardens had as food producers in the 19th century. Since its origins, New Zealand has had to cope with the distance from traditional markets. The geographic condition of New Zealand limited the chances of its cities receiving food from other countries. Wellington, the capital of New Zealand is a good example of this. Along with the other British colonies in Oceania, the remote location of Wellington, only accessed by two roads or sea, suggests that from the beginning of European arrival in 1840 [93], its citizens had to find a way to provide their own food. This set a pattern that saw food grown in the garden up to and even after WWII. In 1943 under the Commercial Gardens Registration Act the New Zealand authorities demanded the compulsory registration of all areas of half an acre or over that were linked with the production and sale of vegetables [31]. At least some of these areas were associated with private gardens, which have always been large in NZ (typically around 800m^2). The 1956 census suggested that during the 1950s 56% of Wellington properties grew potatoes at home and 42% grew at least some vegetables [31]. Since the 1950s the questions related to food production in private gardens have been removed from the census questionnaire. This highlights the importance the government gave in the past to the production of food within urban boundaries and its subsequent impact on food security. Perhaps more importantly, the information describes the potential of private gardens for producing a variety of vegetables within the city. At the same time, if a family produces more than they need, the surplus could be shared with friends and family, or sold in local markets, thus putting money into the local economy. This has been important more recently for post-industrial cities, like Detroit, where urban food growing on 'waste' land has become part of the local economy [25, 26].

The value of growing vegetables at home in terms of their superior quality is often mentioned in gardening books

both past and present [49], although the importance of doing this lessened in the post-WWII world. In the introduction to an NZ Department of Agriculture Bulletin on home vegetable growing, the former prime minister of New Zealand, Walter Nash, urged *"...every citizen who has access to land, to do everything in his power to supply his own family with vegetables"* [73] as part of the World War II 'Dig for Victory' campaign. By 1950 although acknowledging the delight in and superior taste of home-grown vegetables, the advice to the householder with a very small garden was to forgo vegetables in favour of a flower garden as, *"...you can never buy its equivalent from a florist's shop as you can buy vegetables from the green grocer"* [27]. In one view, seeing food as a commodity that is only bought furthers the split between people living in urban areas and the experience of the natural cycles and ecosystems that support such living, creating a sense of alienation between nature and everyday living. This has an impact on the meaning of sustainability. When the link between natural sources and final products is broken, natural limits are abstract, and sustainability becomes a label that is stuck to supermarket higher priced products that are only affordable by a minority.

6. The Potential of Private Gardens

A productive garden would thus seem to provide the opportunity for generating alternative futures and stabilizing urban ecosystems if managed well. However, here the size of the private garden may be critical. The plots provided by Cadbury for the Bournville workers were around 5400ft^2 (502m^2) [44], generous by UK standards but half the classic NZ quarter acre section (10,890ft^2 or 1012m^2). Swarovski in describing the housing in The Tyrol he built for his workers post World War II discusses a 1000m^2 plot (the NZ quarter acre section) as, *"...only then would a garden be of real help in times of need, providing fruit and vegetable and housing domestic animals...modern man should not completely abandon the production of foodstuffs"* [85]. However, modern gardens in many suburbs are nowhere near this size. This suggests private gardens may not be able to grow enough food in times of need.

Green areas inside the city can still offer the possibility of growing food in a cheaper and more accessible way than hydroponic infrastructures or other technologies. From this point of view, conserving the open land of private gardens is like having an asset for hard times. This rationale has been used to link topics like vulnerability, robustness, and risk reduction under the umbrella of resilience. However, the lack of data about the productive capacity of private gardens means that issues like size ad soil quality, and even the skill of householders, remain unknown quantities. Perhaps it would be better to lose private gardens through densification, even if this means an increased environmental impact [77]. The question remains whether private gardens can really contribute to urban food security, and hence urban resilience.

7. Resilience and Private Gardens

One way of answering the previous question is by analysing private gardens as non-built spaces of the urban fabric that form an arena where future changes in a city could take place. Their very existence is what allows densification to happen. The existence, shape, size, morphology and ownership of private gardens depend on changes in the built environment and its context, like the decision to move to compact built environments.

The fact that residential gardens are private response to social and political conditions that are temporary, but that could be changed in the future, opening the door to a wide array of opportunities. It is precisely this ephemeral character of private gardens that makes them spaces that can buffer residential change in a city, in other words, spaces for resilience. This buffering capacity is the future potential that private gardens hold, which is elusive and hard to see in the present but links to the resilience of a built environment. However, they are not necessarily regarded as useful spaces for the city at present since they cannot be seen or used by everybody [39].

Resilience has been often a misunderstood term, not least because it comes in two forms: engineering and ecological resilience [47]. From an engineering approach, resilience means the capacity an object has to recover its original form once it is distorted. The faster a system recovers, the more resilience it shows. However, cities are not rubber bands that can be easily stretched with the expectation they will naturally return to their previous shapes. Moreover, the idea of recovering, which is embedded in engineering resilience, implies that a system will return to the same conditions and circumstances that originated the crisis [56]. The concept of ecological resilience may be more suitably applied in cities to avoid repeating mistakes or resisting true change [33, 34]. In ecology, resilience is the ability of a system to change under external and internal pressures without moving to a different state [91]. In this case, the most important quality to enhance is the adaptive capacity of a system to keep on working while adjusting to a disturbance instead of coming back to a previous state. Resilience is about understanding how change can be used to encourage persistence [35].

The point of discussion is the idea that a system of private gardens may contribute to the capacity of cities to buffer unpredictable disturbances in a general and specific way. The specific resilience is the resilience to particular disturbances affecting one part of the system [90]. For example, in the case of a natural hazard, people could rely on the space provided by private gardens for temporary accommodation. During earthquakes, people tend to abandon their houses and inhabit open spaces, like parks, wide streets, or residential backyards. In these situations, private gardens can contribute to the survival of a community just by providing open available land. After the recent earthquake in Nepal, the families living in houses with gardens had the chance to leave the house and settle in their backyards until a proper assessment of their houses was undertaken. They used the house kitchen for

cooking and slept in tents in their backyards. This also provided them with the advantage of looking after their belongings without risking their lives. Another recent example is the alternative use of front yards after the earthquake in Concepcion, Chile. In 2013, researchers documented how people affected by the earthquake and tsunami in Chile used food produced in backyards to cope with the temporary shutdown in the functioning of the city [1]. Moreover, residential front yards were important for camping and for communicating with neighbours. From this point of view, private gardens could contribute directly to the resilience of human habitats to earthquakes.

Private gardens may also contribute to the general resilience of urban landscapes, general resilience being defined as the resilience of a whole system to multiple hazards that cannot be specified at present. This is because private gardens offer unbuilt spaces that allows elements of the built environment to change [20]. Like private gardens, the urban form of a city is continuously changing which creates both problems and solutions. For example, building more in the same place could give cities the capacity to accommodate more people without sprawl but will also increase rents and the cost of living [13], pushing vulnerable sectors of society to live outside the city. In this case, the management of private gardens so that they are not all built over could mitigate the impact of compaction, which often also causes gentrification. The time scale of general resilience could be larger than that of specific resilience since problems like gentrification tend to affect more than one subsystem or area in the city. Since private gardens are spread across the city, their spaces could be used as part of future solutions to problems not easily foreseen at present.

In San Miguel de Tucuman, Argentina, the old municipal laws meant only a portion of each plot could be built on, saving the rest as part of what was called the "lung of the block". During colonial times, plots in San Miguel de Tucuman were long and narrow in the city centre. Houses were built as a cumulative line of rooms connected by a long verandah that served as circulation. These "sausage houses" persisted for many years until the density in the city centre increased and most were replaced by medium and high-density buildings [35]. This change was possible because the plots were not fully built out in the past. The apartment blocks were designed with a hollow core for light and ventilation. A further increase in density is only possible if the whole block is built on, losing all green space. This shows how the presence of private green space allows for densification up to the point where the only way the city can change is to clear the block or plot and start again [20]. Private gardens can thus offer some resilience to change in aspects such as urban density but there will come a point when this general resilience is insufficient and a major change—complete redevelopment—will occur. This introduces another aspect of ecological resilience, as if private gardens are seen as space for the future growth of the built environment, then eventually the green network of a city would be affected by these changes. Every time the

resilience of a system (moving to lower energy use through densification) is enhanced in one direction will be lessened in another (loss of room for future densification).

7.1. Private Gardens, Heterogeneity and Resilience

If the open areas provided by private gardens are spaces in a city that allow changes to happen, then their design and management could be important. At the moment infill development using private gardens often leads to replication of driveways and more land lost to impervious surfaces than is desirable. The location and shape of private gardens may be as important as the quantity of open space they contain. Green spaces contribute to the morphological diversity of urban landscapes because they represent physical discontinuities within the built urban environment [36]. In ecological resilience, the diversity of an ecosystem plays an important role in its adaptive capacity [2]. The more diverse the ecosystem, the richer, more robust and more complex they tend to be. Using a similar argument, it would be possible to imagine that a diversity of forms for private gardens could make built environments richer and more adaptive because they could accommodate a broader gamut of potential change. A study comparing the development of non-built spaces in the CBD of Auckland, New Zealand and the neighbourhood of Nezu in Japan tends to support the hypothesis that the diversity of private gardens might be linked with the resilience to change of a built environment [38]. Rather than the mere presence of green spaces, whether public or private, it is the interplay between built and un-built spaces and different sizes of gardens that provide diversity in urban landscapes by adding to the heterogeneity of the built environment [37, 68].

7.2. The Example from Christchurch, New Zealand

Another example of the importance of private gardens for the heterogeneity and resilience of a city is found in the built environment of Christchurch, New Zealand. After the 2011 earthquake and the damage to buildings many lots have remained vacant. The government promoted a new plan for the city based on the idea of a more compact city centre with medium-density buildings, surrounded by a wide green belt. However, a study showed that the compaction of the built environment alone would not produce a more diverse urban landscape. The morphological analysis showed it is the interplay between open spaces and built spaces, at all scales, that creates a heterogeneous landscape not the single addition of a big green area. At the smallest scale, private gardens are important contributors to the diversity of the green infrastructure of the city. Moreover, it was the low-density part of Christchurch, characterised by small houses and generous gardens that were less affected after the earthquake.

8. The Design of Private Gardens

If the form of the private garden matters for the resilience of urban landscapes, then, designers, as shapers of the built

environment, could directly contribute to the resilience of the city [34].

Changes to private gardens could be both cultural and physical (Table 2). The cultural dimension is associated with a shift in the social perception, behavioural changes in the garden, changes in policies, ownership or the emergence of alternative ways of controlling and managing these spaces. The physical dimension would be linked with changes made in the form of private gardens. The physical dimension of the private garden is related to its structure, infrastructure, and morphology. However, both physical and cultural aspects must be understood as a single phenomenon because they affect each other. If the perception of a private garden suddenly changes, then it is highly possible that changes in the form and configuration of the garden could occur.

Table 2. The cultural and physical dimension of private gardens.

Strategies	Cultural	Physical
Adaptations	1) Multiple uses: behavioural change. 2) Productive landscape: production of food, energy, recycling and storage of resources. 3) Integration with other gardens.	a. Connection with the street or other gardens within the block. b. Allocate for temporary structures. c. Accretion of biomass. d. Improvement of existing infrastructure.
Transformations	1) Land use change 2) Change in ownership status: shared, public, collective 3) Change in the perception of private gardens. 4) Change in laws, policies, and regulations	a. Reshaping the geometry of the plot (width, length, shape and size) b. Use of the space for different uses than originally planned c. Increase the built density of the plot.

Researchers have suggested two strategies for resilience: adaptations and transformations [91]. Transformations are linked with the redesign of an entire subsystem, in this case, the private garden and everything within its context. These are major changes that involve a new set of rules for governing, using, and perceiving private gardens. The design of transformations would involve the shaping of the elements, infrastructure, and geometry of the plot as well as changes in the land use of private gardens. Adaptations are adjustments to the pre-existing infrastructure or way of functioning. They represent minor interventions. Designers can participate in the adaptation of private gardens by ensuring there are permeable surfaces to avoid storm water run-off problems, or by adding new or multiple uses to a garden. For example, if waste is composted and water is retained in private gardens, food growing at home will also offset the need to bring in nutrients from outside the ecosystem in terms of imported food. In this sense, design can be an important way to establish the links between the morphology of private gardens and their possible influences on the resilience of the built environment.

9. Discussion

The resilience capacity of a plot, block or neighbourhood could be induced by designing adaptations and transformations in private gardens, but whether this resilience is useful will only be demonstrated in the future, after an unpredictable disturbance is buffered by the private gardens. Before that moment the only certainty is that adaptations and transformations of private gardens can be effective in increasing their robustness. Strategies for making private gardens more adaptable, or for transforming them, will only enhance the resilience capacity of the built environment if they can be used to serve different purposes from their original intentions.

The main hypothesis here is that the contribution of private gardens to the general resilience of a city cannot be directly and consciously designed in the present. Nevertheless, whatever the contribution of private gardens to the resilience of a city might be, by keeping land without buildings, private gardens save space for the future, and that saved space can mean the opportunity to keep on living in cities. The potential resilience of private gardens might be found in spaces that were not designed and seem to be useless, unfinished and loose at the present.

This leaves two unanswered questions. How much urban green space should there be, and how should it be distributed if it is to make a contribution to the resilience of the urban system? There is, perhaps a third question over whether it might be better to not have private gardens and simply dedicate public areas to shelter and serve the entire city population. However, the latter brings up the issue of walkability as the one thing a wide scattering of private gardens, however, small, offer is immediate access. These are the issues that now need to be modelled in detail.

10. Conclusion

At present, due to population growth and possible energy shortages, life is being much more closely arranged in urban landscapes. However, there is not yet agreement on where or when this should end, since more urban areas must still rely on outside areas for the resources they need. The competition between different land uses, whether to provide food or habitat, presents a serious issue for planners and urban designers. If the aim is to populate the city in a compact and dense manner, then private gardens could be seen as an obstacle in this process. The paradigm of a compact and sustainable city then becomes a threat to the survival of private gardens. Consequently, irregular or heterogeneous, small front yards or spaces in-between buildings that are important for the resilience of a city, could be in serious jeopardy.

One of the biggest issues with the role of private gardens is to define their benefits for urban living. As this article suggests, the difficulties with this analysis come from the distance between individual and collective interests, private

and public uses, and aesthetic and functional aims. As functional elements private gardens are linked with the ecosystem services that they can provide and with the possibility of satisfying basic (or vital) needs, for example food, and of providing space as a 'buffer' to disturbances in the socio-ecological system. As aesthetic elements of the built environment private gardens can provide beauty and a connection with nature. Unfortunately, they can be also used to highlight socio-economic differences and unfair power relationships. In order to advance the state of the discussion around private gardens it should be acknowledged that although the history of the enclosure of outdoor space is very long, the privacy of such space, which has to be upheld by the laws of the time, is only temporary. It is the space that is important, not the fact that it is currently private.

Essentially the presence of private gardens within the urban matrix represents a social and environmental capital. They are there to be used when city functions become disrupted through natural hazards, and as such are part of the resilience of the city. This also suggests that intensification, which means losing private gardens, could lower the opportunities to cope with future hazards. For this reason, moving toward more compact built environments and smart cities should be carefully evaluated since this threatens the persistence of private gardens. This implies efforts to make cities more sustainable and resilient should reconsider the role of private gardens and acknowledge that they are active and potentially productive spaces with the capacity to accommodate growth, and provide joy and safety into cities.

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