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Typically Diverse: The Nature of Urban Agriculture in South Australia

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Abstract: In our visions of the future, urban agriculture has long been considered an integral part of the 'sustainable city'. Yet urban agriculture is an incredibly diverse and variable field of study, and many practical aspects remain overlooked and understudied. This paper explores the economic sustainability of urban agriculture by focusing on the physical, practical, and economic aspects of home food gardens in South Australia. New data from the Edible Gardens project online survey is presented on a broad range of current garden setups, including a figure illustrating the statistically typical South Australian food garden. The differences between the survey data and a recent optimized garden model further highlight the gap in knowledge regarding existing home food gardens. With regard to the financial accessibility and economic sustainability of home food gardens, there is also still much more work to be done. Although saving money is a top motivation, with many survey respondents believing that they do succeed in saving money, it remains to be seen whether their current gardening practices support this aspiration. Measurement of the full costs of different gardens would allow for better predictions of whether growing food can save household's money and under what circumstances.

Keywords: urban agriculture; urban gardening; economic sustainability; optimization; challenges; measurement; resource efficiency

1. Introduction

In our visions of the future, urban agriculture has long been considered an integral part of the 'sustainable city'. It is anticipated that urban agriculture will contribute to food security, city resilience, conservation of resources, and recycling of urban wastes, and that urban planning could one day transform our cities into farms [1–6]. There are many different forms of urban agriculture (UA): home food gardens, school gardens, collective or community gardens, and urban farms. The focus of this paper is home food gardens in developed countries. As the most dominant form of UA in the developed world [7–9], home food gardens have the potential to greatly contribute to future sustainability.

Many of the practical aspects of UA remain overlooked and understudied [8,10–14]. In relation to home food gardens, such practical aspects include the different production methods or gardening approaches used, the productivity of these different methods, their water efficiency, the full costs involved, and their main benefits and challenges. Home food gardens are also widely spread across urban areas; they are on private property—often hidden behind fences or in backyards—and there is great diversity in the ways people grow food. These characteristics all contribute to the difficulty of conducting research on home food gardens [8,10,15].

The research that has been conducted on UA has often not been able to, or has refrained from, measuring labor, full costs, and water use. As discussed in detail by Pollard, Roetman, and Ward [12],

early research into the economic viability and productivity of UA focused on collecting data from a small number of purpose-built experimental gardens [16–19]. These early studies did measure time and, to some extent, costs, but only one study measured water use. Indeed, to this day, Cleveland, Orum, and Ferguson [16] remain the only in-field UA study to have fully accounted for water use. This is particularly concerning as water scarcity increases and water becomes costlier to both treat and supply. More recent research has measured yields from a greater number of community gardens [20–24] and existing home food gardens [25–27]. The main focus of these recent studies was yield and the retail value of the crops grown. Water was not measured at all, and only Codyre, Fraser, and Landman [25] measured labor and costs. Yet despite the lack of verification, 'growing your own' is still commonly advocated in popular literature as a way for households to reduce their cost of living by saving money on their food bills [28–30].

In addition to the need to consider labor, costs, and water as inputs in their own right, we must also consider the impact of these inputs on the economic sustainability of home food gardens. If the setup or maintenance costs of an urban food garden prove too great a barrier to households wanting to save money, then growing food should no longer be promoted in such a way. Moreover, if UA is intended to be an integral part of our vision for the sustainable city, then it is imperative to know whether the inclusion of UA in this vision adds a net savings or a net cost. Certain garden setups may lend themselves to higher productivity, higher water efficiency, lower labor input, and/or lower costs than others. But without further research into the variety and effectiveness of the myriad garden setups currently used in home food gardens, no recommendations can be made.

In the absence of data, theoretical models can simulate UA and predict potential yields. Because of the lack of in-field UA data available, these models are either calculated based on extrapolated results from small data sets [31] or by using commercial horticulture crop data [32]. Consequently, theoretical models may overestimate garden productivity [33]. One recent example of a theoretical model is by Ward and Symons [34]. Their model was based on commercial data. Time spent was assumed to be discretionary (and therefore not quantified), and water and fertilizer were the only costs included. The collection of new data on the practical aspects (especially time and money) of existing home food gardens would not only provide a more realistic basis for further theoretical UA models, but would also make a considerable contribution to our understanding of the economic sustainability of home food gardens.

The objective of this paper is to explore the economic sustainability of UA by focusing on the physical, practical, and economic aspects of home food gardens in South Australia, as reported by the gardeners themselves. Similar to other countries such as the United States, the United Kingdom, and Germany, Australia is a place of high food security and relatively low food prices. In overall food security, Australia is ranked fifth out of the 113 countries listed by the Global Food Security Index [35]. With regard to food affordability, food constitutes only 10% of total consumer expenditure in Australia—a percentage comparable to those in the United Kingdom (8%), Germany (10%), and Japan (14%) [36]. South Australia is presented as an interesting case study because of its dry climate (receiving an average of 545 mm of rainfall per annum and containing the driest capital city in Australia), high evapotranspiration rates, high price of mains water (currently a tiered mains water price between AUS\$2.27/kL–AUS\$3.51/kL), and large proportion of the population engaged in food production (59%) [9,34,37–40]. New data from an online survey is presented on the area under production, gardening approaches, production methods, estimated inputs, and the challenges faced by urban gardeners. A figure of the statistically typical urban food garden (as based on the median of the category results) is presented to illustrate the present-day home food garden in South Australia. Ward and Symons's [34] recent theoretical model is reviewed in light of the survey data. The discussion then turns to what these results mean for households wishing to save money by growing some of their own food as well as recommendations for future research.

2. Materials and Methods

In September 2016, the "Edible Gardens" project was launched by the Discovery Circle, an initiative that runs citizen science projects, based at the University of South Australia. Edible Gardens (EG) is a citizen science project aimed to investigate the resource efficiency, productivity, and social value of UA in South Australia. An online survey collected a range of data on South Australian home food gardens and was open to all gardeners over the age of 18 within the state. Included in the survey were questions on basic demographics, motivations, challenges or barriers experienced, and practical aspects of the food gardens, such as size, production method, typical crops, water source/s, irrigation method/s, and estimated time and money spent. The survey was designed using the online survey tool SurveyMonkey. This data provides a snapshot of how people are approaching growing food and the diversity of philosophies and activities that exemplify urban food production in South Australia. There is no way to test fully the veracity of this data; however, this survey method is consistent with previous work, such as that by Wise (2014). This project received approval from the Human Research Ethics Committee of the University of South Australia on 8 January 2016 (Protocol number 0000034940).

The survey was promoted on the Discovery Circle website and Facebook page and via other print materials and press releases from the project sponsors: the University of South Australia; the Department of Environment, Water and Natural Resources; the Adelaide and Mount Lofty Ranges Natural Resources Management Board; the City of Salisbury; and the City of Marion. A large number of project postcards were also distributed around South Australia to libraries, garden centers, community gardens, community centers, farmer's markets, and other relevant businesses. During the survey period (September 2016 to January 2018) 379 people responded to the survey. The survey results were analyzed using a combination of Microsoft Excel, IBM's SPSS Statistics Software, QSR NVivo Qualitative Analysis Software, and R 3.4.0 [41] using the NETWORK package [42,43].

3. Results

The results are divided into five categories: demographics, gardening background, physical garden elements, garden inputs, and a theoretical comparison. These categories cover all of the survey questions relating to the practical aspects of the respondents' urban food gardens (for the full list of these questions, please refer to the Supplementary Materials). The results of this study are intended to provide a broad foundation of survey data. It is the intention of the authors to conduct a follow-up study based on in-field garden inputs (such as labor per activity, water use, and costs) and outputs (such as individual crop yields). Therefore, this survey focused more on gardening methods, rather than crop types, as a basis for future comparison of perception and measured reality. Additional results collected by the EG survey, including motivations, social learning sources, food preservation methods, food distribution frequency and recipients, and the value of growing food will be presented in a separate paper.

3.1. Demographics

The Edible Gardens survey respondents ranged in age from 18 to 81+, with a median age-range of 41–50. The majority of the respondents were women (77% female: 22% male: 1% indeterminate/ unspecified). The median number of people living in the household was three, with 34% of households having primary school age or younger children present and 16% having at least one person over the age of 65 present. Postcode data allowed us to map and classify the respondents according to whether they lived inside (82%) or outside (18%) the boundary of metropolitan Adelaide. Figure 1 displays the mapped postcodes across and close to metropolitan Adelaide, the boundaries of which are colored purple on the map. There are 24 additional survey postcodes from across wider South Australia that are not visible in Figure 1.

Figure 1. The Google MyMap of the distribution of the Edible Gardens survey responses. Each green marker shows the location of a unique survey postcode. The bounded region is the Adelaide metropolitan area and the blue marker pinpoints the center of Adelaide Central Business District (34°55′43″ S, 138°35′60″ E).

A number of questions were related to relative socio-economic advantage and were used to contextualize the EG survey participant group within the broader South Australian community. Education levels suggested that our respondents were, on average, substantially more educated than the general population with 35% holding a bachelor's degree and 31% holding a postgraduate degree. By comparison, 14% of South Australians hold a bachelor's degree and only 4% hold a postgraduate degree [44]. Using the survey respondents' postcodes as a proxy for location, we were able to examine their distribution using Australia's Index of Relative Socio-economic Advantage and Disadvantage (IRSAD) rankings. Figure 2 shows the distribution of postcodes of the EG respondents as compared to the rankings for the whole of South Australia. The majority of the EG respondents' postcode index rankings (59%) were above the fifth decile, compared with only 39% of the total South Australian rankings. In particular, the highest two deciles were substantially over-represented and the lowest two deciles were substantially under-represented in our survey respondents (as measured by their postcode) relative to the general population.
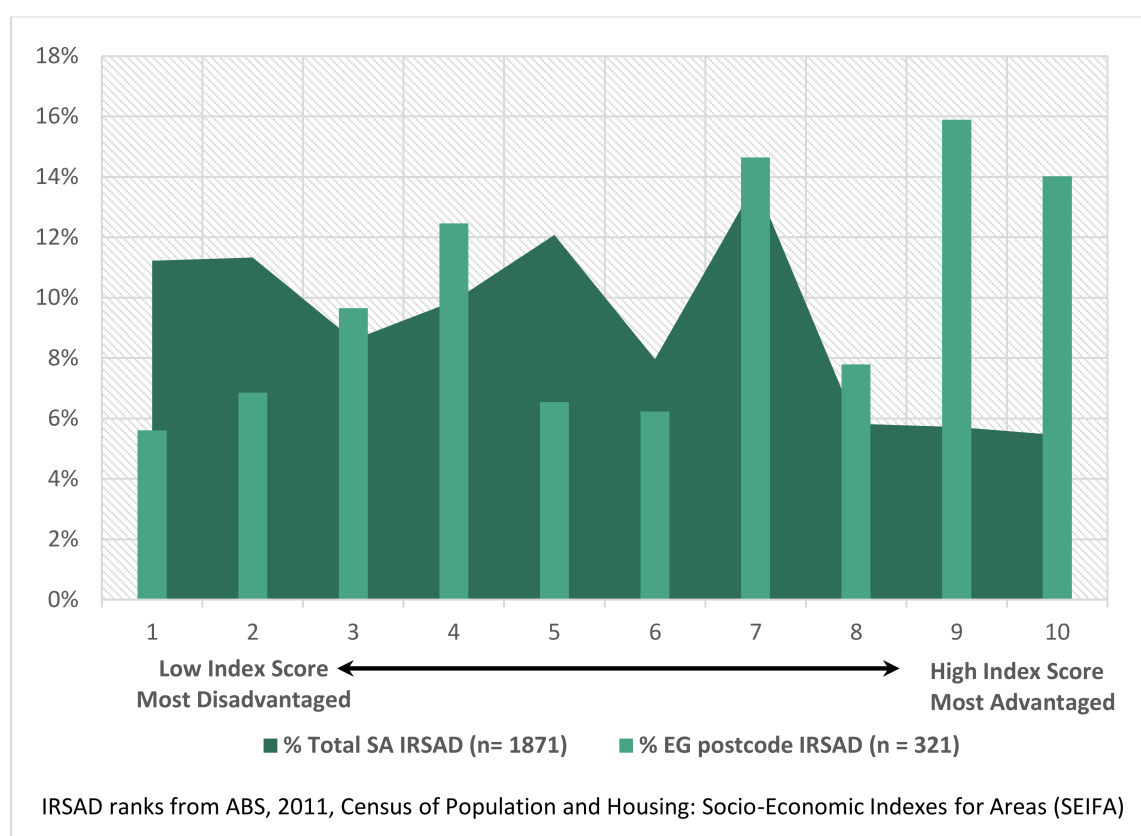
Figure 2. Comparison of the Index of Relative Socio-economic Advantage and Disadvantage (IRSAD) rankings of the Edible Gardens survey postcodes to the rankings of all South Australian postcodes.

Home ownership (defined as either owning a home outright or having a mortgage) was high at 85%. Of those remaining, 11% were renting and 4% had other situations. There were statistically significant differences (see Table 1) between the home owners and home renters, in that home owners had larger food gardens ($U = 6990.5$, $n1 = 270$, $n2 = 35$, $p = 0.001$), spent more money setting up their food gardens ($U = 4875$, $n1 = 241$, $n2 = 28$, $p = 0.001$), had higher IRSAD rankings ($U = 5668$, $n1 = 268$, $n2 = 35$, $p = 0.043$), and had less of a desire to save money by growing food ($U = 3592$, $n1 = 266$, $n2 = 35$, $p = 0.021$). The difference between the home owners and home renters and their desire to save money by growing food (Table 1) was particularly interesting. The same comparison is presented for the two highest and two lowest IRSAD deciles (noting that this uses the respondents' postcode as a proxy). Interestingly, however, no significant difference was found in their perceptions of how much of their weekly fruit and vegetable budget they believed they had actually saved.

Table 1. Comparison of responses to the statement "I produce food to save money": home owners vs home renters; and lowest 2 Edible Gardens postcode ranks of Index of Relative Socio-economic Advantage and Disadvantage vs highest 2 Edible Gardens postcode ranks of Index of Relative Socio-economic Advantage and Disadvantage.

Responses	Home Owners ($n = 278$)	Home Renters ($n = 36$)	Lowest 2 IRSAD Scores ($n = 39$)	Highest 2 IRSAD Scores ($n = 76$)
Strongly Disagree	2%	3%	3%	3%
Disagree	12%	8%	8%	14%
Neutral	30%	19%	15%	32%
Agree	42%	33%	49%	41%
Strongly Agree	14%	36%	26%	11%

3.2. Gardening Background and Approaches

Food gardening experience was categorized as follows: 'Less than 1 year', '1–5 years', '6–10 years', and '11+ years'. The median response was 6–10 years. Although there was a weak positive correlation between the age of the respondents and their years of gardening experience (Spearman correlation: $r_s = 0.357$, $n = 332$, $p = 0.001$), this was not true for everyone. The 29 gardeners who reported having 'less than 1 year' of experience ranged in age from 18 to 60 years, and the 116 gardeners who reported having '1–5 years' of experience ranged in age from 21 to 80 years. With regard to gardening consistency, 62% of the respondents reported growing food 'all through the year', while 18% grew "on and off again" and 14% grew food 'seasonally'.

In an attempt to build up a picture of the 'look' and 'feel' of food gardens in South Australia, gardening approaches were categorized differently from production methods. The list of production methods began as a simple list of different physical methods to grow food; however, there was a need to be able to clearly identify urban livestock as they require specific physical setups. Additionally, fruit trees were identified as an interesting crop/form of food production—one with the potential to grow large volumes of food without too much effort on the part of the gardener. As fruit trees can be grown in in-ground beds, raised beds, pots, or even wicking beds, they were added as an individual production method for easy identification.

Gardening approaches were categorized as the more philosophical approaches with which gardeners may identify. Ten different gardening approaches were listed (based on common approaches used in South Australia and those mentioned previously in the literature [27,45]) and survey respondents were asked to select all the approaches they used (Figure 3). This question was included as different gardening approaches are commonly advocated as ways to improve a garden and are thought to influence many of the practical aspects of UA; for example, organic gardening may require fewer pesticides, and how adding compost can improve the water retention of the soil.
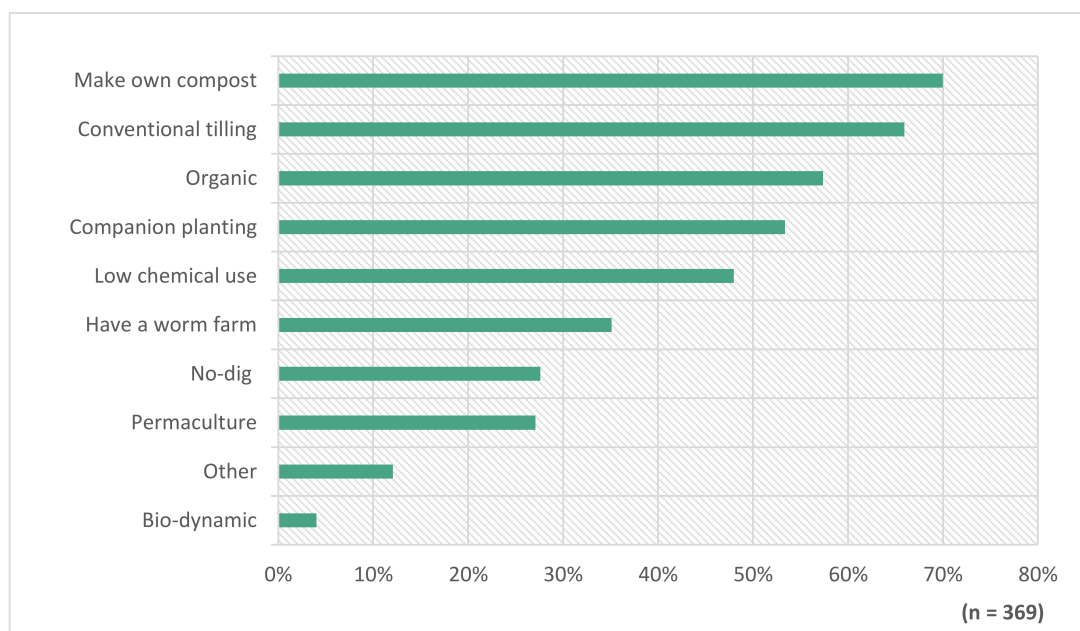

Figure 3. Gardening approaches practiced by the Edible Gardens survey respondents. These approaches are not mutually exclusive.

The median number of gardening approaches with which the respondents identified was four. The top five were composting (70%), conventional digging and tilling (66%), organic gardening (57%), companion planting (53%), and low use of chemical fertilizers and pesticides (48%). There were stronger relationships between certain gardening approaches than between others; for example,

respondents who used conventional digging and tilling were more likely to also use a low amount of chemical fertilizers and pesticides (78%), yet they were less likely to use no-dig gardening (38%) or permaculture (45%). Whereas respondents who used a biodynamic approach were more likely to make their own compost (93%), use an organic approach (87%), and utilize companion planting (73%), they were less likely to use a low amount of chemical fertilizers and pesticides (33%).

The challenges of growing food in urban areas were split into two questions. First, respondents were asked to list the top three things that delayed or challenged them when they initially began to grow food. Then, they were asked whether there was anything currently making it difficult for them to continue growing food, and if they responded "yes" (as 61% did), they were asked to describe those current challenges (Table 2).

Table 2. Comparison of initial and current challenges to growing food in urban areas. In both questions, each respondent was given the opportunity to identify multiple challenges.

	Initial Challenges (*n* = 904)	%		Current Challenges (*n* = 272)	%
1	Lack of time	50	1	Lack of time	28
2	Unsuitable conditions	36	2	Unsuitable conditions	21
3	Lack of knowledge	28	3	Water issues	12
4	Lack of space	25	4	Livestock, pet, or pest issues	12
5	Cost	20	5	Physical or health issues	11
6	Water issues	17	6	Lack of space	8

Is there currently anything that makes it difficult for you to continue to grow food?
'Yes' = 61%, 'No' = 38% (*n* = 376)

3.3. Physical Elements of the Food Gardens

The physical elements of the respondents' food gardens included the area under production, the types of growing areas, and the total number of growing areas. The total area under production was categorized as follows: tiny (<4 m^2 (7%)), small (5–15 m^2 (28%)), medium (16–20 m^2 (28%)), large (31–50 m^2 (16%)), and huge (51+ m^2 (16%)) (see Figure S1). The median size under production was medium (16–20 m^2). The total area under production did not refer to the size of the entire garden, but purely to the space dedicated to food production.

A wide variety of production methods were being used (Figure 4). Fruit trees were the most common method (84%) followed by pots and planters (74%), in-ground beds (70%), raised beds (61%), chickens (39%), wicking beds (21%), bee hives (8%), other production methods (7%), vertical gardens (7%), other poultry (5%), and aquaponics (4%). As shown in Figure 5, the strength of the relationship between the different production methods varied. The stronger the connecting line, the greater the likelihood that both production methods were present together in a single food garden. The median number of production methods used was four. The majority of respondents (68%) were using either three, four, or five different production methods simultaneously in their food gardens. The production methods could be grouped according to the number of other production methods likely to also be present in that same garden. In-ground beds, raised beds, pots and planters, and fruit trees were all more than 50% likely to be present with three other production methods. Chickens were more than 50% likely to be present with four other production methods. Vertical gardens, other poultry, wicking beds, and bees were all more than 50% likely to be present with five other production methods, and an aquaponics system was more than 50% likely to be present with more than 6 other production methods. The number of food producing areas ranged from 1 to 20, with four being the median number of areas.
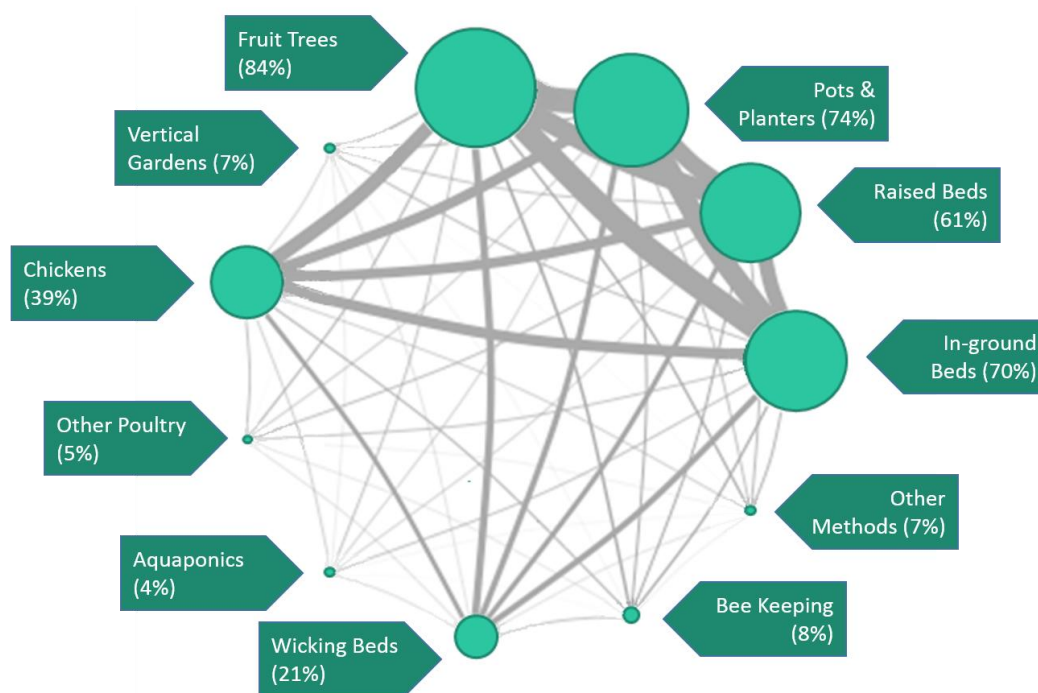
Figure 4. A weighted relationship network of production methods. The size of the circles represents the percentage uptake of the production methods by the Edible Garden (EG) survey respondents. The thickness of the connecting lines represents the strength of the relationship between the two production methods, as defined by the likelihood of both being present in a single garden.

3.4. Garden Inputs

The main garden inputs about which the respondents were asked included time, water, and money. The survey respondents estimated the time spent per week on their food gardens, ranging from less than one hour to more than 20 h (see Supplementary Figure S2). The most common category of time spent per week was 1–5 h (55%), and the median was four hours. Statistically, there was no difference between the hours spent by men and women (U = 4,107.5, $n1$ = 199, $n2$ = 50, p = 0.056). Some children (less than 18 years of age) did help out in the food gardens, although generally for only one hour per week (median = 1 h, range = < 1–10 h).

As reported by Pollard, Ward, and Roetman (submitted for publication), the survey respondents reported a range of water sources, including mains, rainwater, grey water, and recycled/blended water, as well as 'other' sources. Respondents dispensed that water using a variety of irrigation methods, including manual irrigation (via hose, watering can, or bucket), drip irrigation, sprinklers, wicking beds, and any method of providing water for animals, as well as 'other' methods. Both the water source and irrigation methods reported were not mutually exclusive, with the majority of survey respondents using more than one water source and irrigation method. The respondents were also asked to estimate their water use, yet we found that most respondents had very little idea of how much water they actually used in their food garden areas. Owing to the large diversity of water sources (five in total) and irrigation methods (six in total), we concluded that 'estimated water use' was too complex a term to accurately provide a quantifiable result via survey. Future work collecting in-field water use data would be more accurate and beneficial.

A broad range of estimated setup costs were reported by the survey respondents with high variability (Figure 5). This variability was partially due to the differing levels of detail in the responses. Some respondents included only the cost of seeds or seedlings, others added the cost of soil, fertilizer, and building supplies, and some went to great levels of detail, documenting not only the building of garden beds/wicking beds/orchards, but also the purchase and installation costs of new rainwater

tanks, irrigation systems, or grey water recycling systems. The setup costs therefore ranged from $0 to AUS$20,000, and the median amount spent was AUS$500. There was a moderate positive correlation between the area under production and garden setup costs (Spearman correlation: $r_s = 0.432$, $n = 304$, $p = 0.001$).

When asked to estimate their monthly garden expenses, again there was a broad range of responses from $0 to AUS$1000 per month, with a drop off after AUS$50. The median amount spent was AUS$30 per month. There was a correlation between the total area under production and the monthly costs ($r_s = 0.379$, $p = 0.001$, $n = 325$).

Analysis confirms that there was a significant difference between several other parameters for gardens costing AUS$50 or less per month versus gardens costing more than AUS$50 per month. Gardens costing more than AUS$50 per month had higher setup costs, were larger, had a greater number of food producing areas and production methods in use, and took more time to tend. Gardens that cost more than AUS$50 had higher mean ranks for the areas under production ($U = 8143.5$, $n1 = 279$, $n2 = 46$, $p = 0.003$), a greater total number of production methods ($U = 8143.5$, $n1 = 279$, $n2 = 46$, $p = 0.002$), a greater total number of food producing areas ($U = 8338$, $n1 = 279$, $n2 = 46$, $p = 0.001$), a greater number of weekly hours spent gardening ($U = 8398.5$, $n1 = 272$, $n2 = 46$, $p = 0.001$), and a higher total setup cost (no outliers) ($U = 6534.5$, $n1 = 254$, $n2 = 35$, $p = 0.001$).
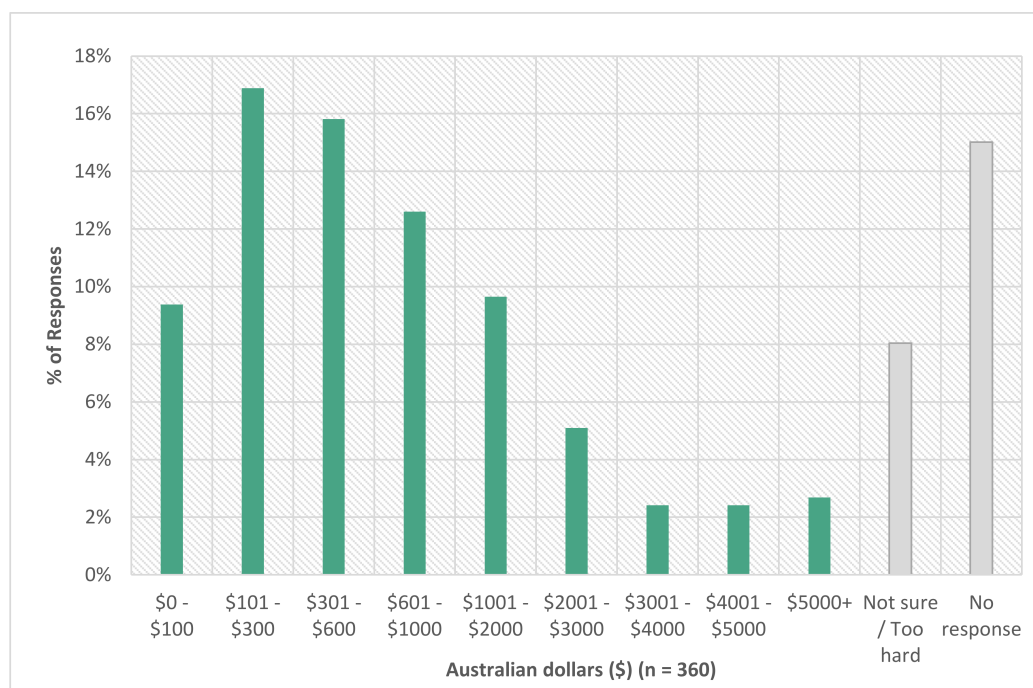

Figure 5. Estimated setup costs of food producing areas. Some respondents found it difficult to estimate their setup costs, hence the "not sure" and "too hard" responses.

There were also some significant differences between gardeners who spent less than AUS$10 per month and those who spent more than AUS$10 per month. While the majority of both groups agreed that they grew food to save money, those who spent less than AUS$10 per month were more certain that they succeeded in saving some portion of their household fruit and vegetable budget (Mann–Whitney U test: $U = 5243$, $n1 = 58$, $n2 = 219$, $p = 0.038$, difference ($\leq$10–>10) = 1.00 (CI 95% 0.00 to 1.00)).

Building on the initial cost questions, the survey respondents were asked whether they thought they succeeded in saving money in their weekly household fruit and vegetable budget and if so, to what extent (Table 3). In all, 47% believed that they did save some amount of their fruit and vegetable budget, 13% were unsure, 13% thought they broke even, 14% didn't think they saved any

money, and 6% were adamant that they did not save any money. There was also a moderate positive correlation between respondents wanting to save money and thinking that they succeeded in doing so (Spearman correlation: $r_s = 0.515$, $n = 297$, $p = 0.001$).

Table 3. Home food gardener responses to the question "Do you save some portion of your household fruit and vegetable budget by growing some of your own food?".

Available Responses	Responses (n = 358)
Unsure	14%
No, I know I don't save money	6%
No, I don't think I save money	14%
I think we break even	12%
Yes, 0–5% of my weekly household produce budget	13%
Yes, 6–25% of my weekly household produce budget	15%
Yes, 26–75% of my weekly household produce budget	16%
Yes, over 75% of my weekly household produce budget	4%

3.5. Theoretical Comparison Results

Ward and Symons [34] sought to maximize the net value of hypothetical urban food gardens according to the area under production, by considering the nutritional value and water efficiency of crops in different climates. Two-stage linear programming was used to select an optimal mix of crops according to their water use and dietary value. Constraints were applied to ensure that the model selected a combination of crops from a range of dietary food groups—thus better mimicking the mixed-crops common to home food gardens. This approach was intended to produce a more realistic garden model rather than to optimize purely by yield or crop retail value, which tends to select only single high-yielding, high-value crops (a "cash crop") that would be unrealistic at the household garden scale. Ward and Symons [34] contributed the idea that the size of a garden and how it is watered are important to the economic sustainability of urban food gardens, but their model did not allow for the consideration of the related expenses or the labor invested.

The EG survey results, which are applicable to the Ward and Symons [34] optimization model include the number of people in the household, their years of gardening experience, the size of the area under production, and the types and number of production methods used. Ward and Symons [34] calculated optimized crop mixtures for different climates and various sized areas under production as m^2 per person. The majority (70%) of the EG survey respondents had less than 15 m^2 (category 1: tiny (<4 m^2/person) (21%) and 2: small (5–15 m^2/person) (49%)) of area under production per person in their household (see Supplementary Table S1). According to the optimization model, these gardens would ideally be growing a limited range of crops suitable for Adelaide's climate, namely: broad beans, basil, zucchini, strawberries, tomatoes, and eggs. While the EG survey did not specifically ask respondents which crops they grew, it did ask which production methods they utilized from a list of 11 possible methods (for example, raised gardens beds, fruit trees, keeping chickens, etc.) Without specific crop data, it was difficult to calculate whether or not the EG respondents were following anything akin to the optimized mix recommended by Ward and Symons [34]. However, according to their areas under production, the EG respondents were theoretically well-placed to achieve the best possible returns for water applied per unit area and net value.

Keeping chickens for egg production is an interesting production method, with 39% of the EG survey respondents listing 'Poultry—Chickens', 5% of respondents listing 'Poultry—Other', and some respondents listing both chickens and other poultry. In the optimization model, chicken eggs were consistently selected for all area categories as being both a high-value and water-efficient crop for urban food gardens.

Fruit trees are one of the main points of difference between the optimization model and the EG survey data. Fruit trees were present in 84% of the EG respondents' gardens, making them the

most common production method. In contrast, although a range of fruit trees were available in the optimized model, none were selected for their crop value or water-use efficiency in gardens smaller than 80 m^2/person. At 80 m^2/person, orange trees were selected for all climates, and once the model reached 160 m^2/person, almond trees were also selected but only for Hobart's climate.

4. Discussion

4.1. South Australian Home Food Gardens

Due to past observations in the previous literature regarding variable yield rates and different growing approaches in urban agriculture generally, it was anticipated that there would be a reasonable level of diversity among the EG survey respondents' food gardens. Once analyzed, the EG survey results revealed the full extent of home food garden diversity. Figure 6 is a graphical depiction of a statistically typical urban food garden based on median survey results from the EG project.
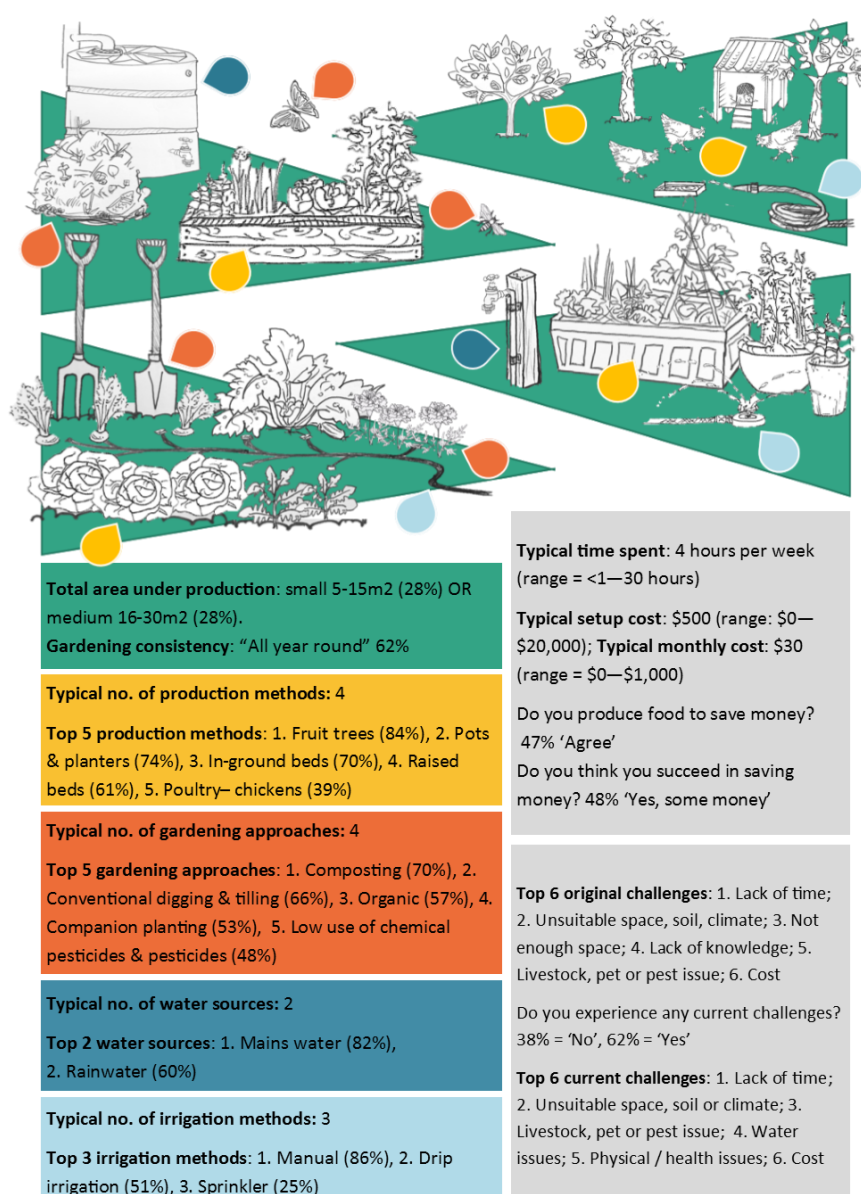

Total area under production: small 5–15m2 (28%) OR medium 16–30m2 (28%).
Gardening consistency: "All year round" 62%

Typical no. of production methods: 4

Top 5 production methods: 1. Fruit trees (84%), 2. Pots & planters (74%), 3. In-ground beds (70%), 4. Raised beds (61%), 5. Poultry– chickens (39%)

Typical no. of gardening approaches: 4

Top 5 gardening approaches: 1. Composting (70%), 2. Conventional digging & tilling (66%), 3. Organic (57%), 4. Companion planting (53%), 5. Low use of chemical pesticides & pesticides (48%)

Typical no. of water sources: 2

Top 2 water sources: 1. Mains water (82%), 2. Rainwater (60%)

Typical no. of irrigation methods: 3

Top 3 irrigation methods: 1. Manual (86%), 2. Drip irrigation (51%), 3. Sprinkler (25%)

Typical time spent: 4 hours per week (range = <1—30 hours)

Typical setup cost: $500 (range: $0—$20,000); **Typical monthly cost**: $30 (range = $0—$1,000)

Do you produce food to save money? 47% 'Agree'
Do you think you succeed in saving money? 48% 'Yes, some money'

Top 6 original challenges: 1. Lack of time; 2. Unsuitable space, soil, climate; 3. Not enough space; 4. Lack of knowledge; 5. Livestock, pet or pest issue; 6. Cost

Do you experience any current challenges? 38% = 'No', 62% = 'Yes'

Top 6 current challenges: 1. Lack of time; 2. Unsuitable space, soil or climate; 3. Livestock, pet or pest issue; 4. Water issues; 5. Physical / health issues; 6. Cost

Figure 6. A sketch of the "typical" home food garden based on the median survey results from the Edible Gardens online survey (*n* = 379). The colored markers in the image relate to the colors in the reference table and represent the different aspects of the "typical" garden.

We found a great diversity of garden setups, garden inputs, and gardeners themselves. This diversity confirmed the results of Wise [9], who found it difficult to describe the "typical" Australian home or community gardener, the survey results showed that the EG respondents ranged in age from 18 to over 81 years. One-third of the respondents had young children (primary school age or younger) and one-sixth had someone over the age of 65 present in the household. There was, however, a prevalence of respondents who were female (77%), home owners (85%), and highly educated (66% holding a bachelor's degree or higher). The combination of the high number of home owners, high education levels, and the disproportionately high IRSAD rankings indicates that the majority of the EG survey respondents are in a position of relative socio-economic advantage.

Much of the difficulty of studying urban food gardens lies in the sheer diversity of garden setups. When every food garden is different, how can they be accurately measured or compared? Two of the underlying differences among food gardens include gardening approaches (Figure 3) and production methods (Figure 4). Past UA yield studies have tended to focus more on where the food gardens were located and what crops were being produced, while only occasionally referencing the production methods used [9,15,21–25]. Zainuddin and Mercer [27] were one of the few to notice the extensive range of practices used in their study of home food gardens. They found that most of their participants made use of more than one practice, thus making categorization challenging. Each of these practices (which we have separated into "gardening approaches" and "production methods") have individual advantages and disadvantages, which could in turn impact the resource efficiency and productivity of each food garden. Figure 6 shows that the EG survey respondents typically make use of a combination of four different gardening approaches and four different production methods. It was anticipated that the most dominant gardening consistency would be seasonal, with people growing food during spring/summer but then letting the garden lie fallow over autumn/winter. However, this was not the case with the majority of the EG respondents (62% were growing 'all through the year'). Upon reflection, with such a large proportion (42%) of the EG respondents reporting having 11+ years of gardening experience, the categories could have been extended further. Yet this question was initially designed to identify less experienced respondents, rather than to measure the full range of experience.

4.2. Differences between the 'Optimized Garden Model' and the EG Survey Data

When comparing the EG survey data with the optimized garden model by Ward and Symons [34] some key differences were found. These differences included the prominence of fruit trees, the value of time, and the likelihood of yield variability. The very high prevalence of fruit trees in small South Australian home food gardens—when they were not selected at all by the optimization model due to low yield and high water demand—has several plausible explanations. It is possible that fruit trees, once established, are a particularly resilient type of food production, which can produce reasonable yields even when little time and effort is devoted to them. Had the optimization model included labor inputs and constraints, perhaps fruit trees would have emerged in preference to higher-yielding (but more labor-intensive) vegetables. Historically, small orchards were a common feature of the typical "quarter-acre block" dominating South Australian suburbs until relatively recently [46,47]. It is possible that many of the established fruit trees being tended by the EG respondents are left over from larger gardens even as house blocks are sub-divided into smaller areas [46]. Moreover, in the last five years, the price of mains water in South Australia has risen dramatically [34,48], so there are likely to be trees planted perhaps as recently as 10 years ago that may have made greater economic sense then, but are now costing more to irrigate. Future research could explore the relative costs and benefits of replacing established fruit trees with new vegetable gardens; it may be that the greatest cost-benefit ratio comes from maintaining fruit trees that are already established.

Due to the lack of in-field UA data available on various crop yields, Ward and Symons [34] had no option but to base their optimized garden yields on consistent commercial yield rates. As home food gardens do not need to account for commercial machinery access, they can pack more plants into

a smaller area—thus potentially achieving higher yields per square meter [49]. This seems particularly relevant for urban fruit trees, which can share at least some of their space with other garden uses (both productive and recreational). However, such advantages remain largely unquantified, with high yield variability noted by many UA studies [20,23–27].

Gardener experience may also influence the productivity of a food garden. Codyre, Fraser, and Landman [25] observed a general relationship between the length of time gardening and the efficiency of their gardeners (efficiency was calculated as high production rates and lower input costs of their food producing areas). This aspect of gardener experience is worth investigating further in future UA research. Understanding gardener experience may even offer an additional explanation for the popularity of fruit trees over vegetables, as it is plausible that trees are viewed by less experienced gardeners as being more forgiving of mistakes.

Applying a value to time invested can be complex. Ward and Symons [34] assumed time spent to be discretionary, thus their model cannot make recommendations on crop types suitable for those with less time. With 'lack of time' listed as both the top initial and top current challenge, it would be worthwhile to attempt to incorporate time in any future garden models. Even without applying a wage rate to the time spent, time-poor urban gardeners would benefit from guidance on which crops or production methods provide the greatest return on time invested.

In summary, it appears that real-world home food gardens differ from "model" food gardens chiefly through their inclusion of fruit trees as a widespread production method. Further work is necessary, especially the incorporation of better yield data and time, capital, and ongoing costs into the model. All of these parameters are likely to have a significant influence on the model of an optimal food garden.

4.3. Challenges to Home Food Gardening

The EG survey asked about initial and current challenges to the respondents' food production. While all respondents answered the initial challenges question, only 61% reported having any current challenges. Both the top initial and top current challenge was lack of time. The idea of people not having enough time, or the perception that growing food requires a considerable amount of time, is commonly documented in past UA studies [9,15,50–52]. The EG survey respondents also estimated the amount of time they spent on their food gardens per week. Weekly time spent ranged from less than one hour to more than 20 h, with a median of four hours. While four hours may sound like a lot, when distributed over an entire week this is approximately 30 minutes per day. The amount of time spent estimated by the EG respondents was considerably higher than that reported by Wise [9]. Wise [9] asked respondents to estimate the time they spent in the last month on their food gardens. Wise's [9] results suggested that 19% of people spent less than 15 min per week, 60% spent between 15 min and 2.4 h per week, and 22% spent more than 2.6 h per week. While the EG survey data gives an estimation of how much time our respondents think they spent on their food gardens, more work is required to gather in-field garden data on the actual time spent. There may be differences in time spent among various gardening activities, production methods, gardening approaches, crops, or irrigation methods. One example of this is Cleveland, Orum, and Ferguson [16], who found that they spent approximately 50% of their time watering by hand. They were one of the few to record labor data by activity. Labor data collected on different food gardens and activities would provide some insight into which methods are best suited to those who lack time.

The challenge category of 'unsuitable conditions' related to unsuitable space, soil, and general garden conditions, such as "not enough sun" or "too hot in the summer". 'Unsuitable conditions' held its place at number two in both lists of initial and current challenges. This challenge appears differently in past UA research: Wise [9] reported the top barrier as '[n]ot enough/unsuitable space'; Conway [50] reported both 'shading' and 'lack of space' as top barriers; and 'lack of space' was reported by Zahina-Ramos [52]. It is also possible that in previous UA research, perceptions of 'lack of space' were indistinguishable from having 'unsuitable conditions', particularly for gardeners with little

experience. Inexperienced gardeners may not realize how many food plants can be packed into small spaces, nor be aware of space-saving growing techniques, such as growing food in vertical gardens, in window boxes, or even on their street verge.

There was an interesting transition in the top challenges from initial to current (Table 2). 'Lack of knowledge' and 'cost' were replaced on the list by 'water issues' and 'physical/health issues'. It is possible that as knowledge and experience with food production increases, the health and physical capability required to accomplish the more strenuous gardening tasks can decrease. The level of people's gardening experience has been suggested in past research to be correlated to their overall productivity [20,25]. Conway and Brannen [10] conducted a study in Canada on home food gardens as a landscaping choice and found that one-third of their study participants had only begun edible food gardening within the last five years. Conway and Brannen [10] and Wise [9] discuss the high turnover of those taking up and then abandoning their food gardens. People with less gardening knowledge and experience are more likely to encounter failure early on, and this disappointment can lead them to give up on their food gardens [9].

Water in urban food gardens is often overlooked. Not only is water a vital input for gardens, but in many places around the world fresh water is becoming scarcer and more expensive. The water use of UA remains challenging to measure, and indeed, only one study—three decades ago—has reported both water use and water cost [16]. The EG survey respondents typically made use of two water sources and three irrigation methods (Figure 6). Water issues appeared at number six on the list of top initial challenges and number four on that of current challenges. By comparison, water was not mentioned as a challenge or barrier by several previous UA studies [9,15,50–52]. This difference may partly be due to the greater water awareness of South Australians as residents of the driest state in Australia [37].

Livestock, pet, pest, or wildlife issues remained as both an initial and a current challenge for gardeners. The majority of the comments related either to an animal or pest coming into the food garden and eating the produce or simply causing damage to the garden. This particular challenge did not appear in the Australian survey by Wise [9], but "attracting animals/insects" was a top barrier in the Canadian study by Conway [50], and insect pests were briefly mentioned in the American study by Zahina-Ramos [52]. Coupled with our respondents' high affinity for organic and low-chemical gardening approaches, appropriate pest management appears to be an area worthy of further research. In general, a better understanding of that which can hinder or prevent people from growing food, or even cause them to cease growing food altogether, may assist in designing the right kind of support.

4.4. Implications for Economic Sustainability of Home Food Gardens

There remains considerable discussion around the potential capacity for UA to support urban food security and reduce the cost of living for households [7,9,14,49,53]. A survey by Butterfield [7] reported that 54% of American households were growing food in order to save money on their food bills. In Australia, 91% of the home and community gardeners in Wise's [9] study slightly or strongly agreed that they save money by growing some of their own food. Wise [9] did however conclude that there is not enough evidence to support the argument that growing food in urban areas saves households money. Indeed, Conway [50] found that only one of his participants identified saving money as a motivation, while 16% actually reported the cost of growing food as a barrier. In order for UA to flourish and be sustained, careful attention should be paid to whether the activity can, or should, be expected to save households money.

The EG survey respondents' high education levels, high percentage of home ownership, and high relative IRSAD rankings indicate that the majority of the EG respondents were not the households that would most benefit from financial savings. This is not to say that our survey respondents did not wish to save money; indeed, 42% 'agreed' and 17% 'strongly agreed' that they grew food to try to save money. When asked whether they believed that they succeeded in doing so, 48% believed that they saved some portion of their household fruit and vegetable budget.

While 'cost' was one of the top initial challenges for people, it did slip slightly down the list of top current challenges to lower than 'lack of space'. The fact that cost was an initial challenge for our survey respondents suggests that it would also be the case, if not more so, for lower-income households. Initial outlay (and ongoing expenses) are important factors when trying to assess the financial feasibility of home food gardens. Measurement of production costs has only been selectively included in past studies [20–23,25–27,34]. The initial outlay required to set up a food garden may present a serious fiscal challenge, particularly for households with little disposable income. Of course, not all of the EG survey respondents spent large sums of money setting up their gardens, with 9% spending less than AUS$100. Indeed, the median setup amount was AUS$500 and the full range was AUS$0–AUS$20,000. The monthly amounts people reported spending on their gardens ranged from AUS$0 to AUS$1000, with a median amount of AUS$30.

Seperate from the strict weighing of costs versus net savings, is the older concept of 'thrift'. Thrift is defined as "the quality of using money and other resources carefully and not wastefully". Being thrifty by growing some of your own food has strong ties to living a less wasteful and more ecological lifestyle [47]. Indeed, as use of the word 'thrift' diminished around the 1950s, it did not take long for a new word—'sustainability'—to rise in its place [54]. Some home food gardeners may view their time and money as worthwhile resources to spend in exchange for engaging in other sustainable behaviors, such as composting their food and garden wastes or caring for the environment by growing food organically. Of course, there are also the well-documented social, mental, health, and education benefits associated with engaging in and practicing UA [55–60].

At this point in time, based on the survey results, it remains unclear whether producing food in urban areas is fully accessible to lower-income households. Yet there is an opportunity to study which food garden setups (production methods, crops, gardening approaches, water sources, irrigation methods, etc.), best lend themselves to low-cost methods to assist in increasing the financial accessibility and economic sustainability of home food gardens.

4.5. Recommendations for Future Work

The authors strongly recommend further research into the sustainability of UA, particularly via in-field data collection on a range of home food gardens. There should also be a focus on collecting consistent, year-round input data, including time spent, water-use, and expenses for a variety of different production methods and crop types. Gardener experience is another variable worth taking into account. In order to respect the diverse variety of existing UA, it is important that this data be collected on existing urban food gardens as they are currently designed and managed. Doing so will provide realistic data on the resource efficiency, productivity, and requirements of food gardens in modern urban areas.

5. Conclusions

Urban agriculture is an incredibly diverse and variable field of study. Past research into home food gardens observed a variety of crops, yield rates, growing periods, gardening approaches, and garden placements. The Edible Gardens project has revealed further variety in production methods, water sources, irrigation methods, sizes, labor, and costs of urban home food gardens in South Australia. Each of the three facets of sustainability—social, economic, and environmental—are likely to be influenced in different ways by the diversity of UA. With regard to the financial accessibility and economic sustainability of home food gardens, there is still much more work to be done. Although saving money was a top motivator for the EG respondents, with many believing that they succeeded in saving money, it remains to be seen whether their current gardening practices support this desire. Measurement of the full costs of different gardens would allow better predictions of whether growing food can save households money and under what circumstances. Lack of time, in particular, continues to be a challenge for urban food gardeners. The differences between the optimized garden model by Ward and Symons (2017) and the EG survey data further highlight the gap in knowledge regarding

existing home food gardens. In particular, a high prevalence of fruit trees was reported by the EG respondents, in contrast to the complete lack of fruit trees in Ward and Symons's optimized garden design (where the model deemed trees to have low yield and high water use). These discrepancies may relate to nuances around different levels of gardener experience, established trees already existing in gardens, and the suitability of trees for time-poor gardeners. All of the findings in this study indicate that UA is a field that is ripe for further research.

Supplementary Materials: The following are available online at http://www.mdpi.com/2071-1050/10/4/945/s1, Figure S1: Total area under production reported by the EG survey respondents, Figure S2: Estimated average time spent per week by the EG respondents on their food gardens, Table S1: Comparison of the EG area under production categories with the square meter per person categories from Ward and Symons's (2017) optimized garden model, and the full list of reported survey questions.

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