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Evidence of COVID-19 pandemic influence on well-being produced by urban gardening: a before-after study

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The COVID-19 pandemic showed us that maintaining and increasing individual and community resilience is essential, particularly in cities. Access to urban green spaces such as parks and gardens supports resilience and well-being. Here, we studied how the pandemic influenced the attitudes towards and outcomes of urban box gardening in the city of Turku in Finland. We analyzed this small-scale social-ecological system before and during the pandemic in 2019, 2020, and 2021. We find that box gardening's importance increased for many gardeners due to the pandemic, supporting that box gardening can enhance resilience. We find that gardeners remain motivated to cultivate but contrary to expectations, they report receiving fewer benefits, suggesting the pandemic's negative influence on well-being extends to urban gardening. Our findings highlight the manifold and long-term influence of disturbances. The long-term changes in attitudes and outcomes suggest that the pandemic's influence on urban gardening might be even transformative.

The majority of the world population lives in cities and the share is rapidly increasing[1]. Urban areas are compact and their functions are highly interconnected, which makes the urban populations vulnerable to rapid changes, such as climate change and pandemics[2,3]. Therefore, maintaining and increasing individual and community resilience is crucial[4,5]. Individual resilience considers the ability of individuals to adapt and recover from adversity where internal resources as well as social support play an important role[3,6]. Community resilience is defined as the adaptive capacity of its social system, improved by for example social networks, social capital, and collective learning[7]. Disturbance can also cause beneficial transformation where a system evolves in a way that improves resilience[2,3]. Urban green spaces and urban green commons have repeatedly been proven to support systemic, individual, and community resilience[3,8–11]. Public urban green spaces are manifold such as parks, reserves, community gardens or trees[12]. Urban green commons are urban green spaces such as community and allotment gardens which depend on collective organization and management[8,9,11–13]. Urban green spaces support resilience by creating critical ecosystem services[8,14,15]. They promote mental as well as physical health, local biodiversity, social cohesion, and social networks[16–19]. However, similar to other shared resources, urban green spaces face threats of overuse, and conflicts over the land use and distribution of benefits[20,21]. Even though European cities are striving to integrate urban green infrastructure in city planning for their multiple ecosystem services[22], at the same time the share of green space is decreasing due to densification processes[23,24].

The COVID-19 pandemic resulted in social distancing, restrictions, and lockdowns all over the world to slow down its spread[25]. According to the Social-Ecological Systems (SES) framework, changes in the social, economic, and political settings greatly influence the sustainable outcomes received from SESs[20,26]. The COVID-19 pandemic significantly changed these settings, such as economic development, political stability, or market incentives, locally and globally. Therefore, it is not a surprise that the attitudes towards and outcomes from the urban green spaces would change. Fast changes in routines, uncertainty, social isolation, and physical threat challenged the resilience of individuals and communities. People reported feelings of depression, loneliness, and anxiety, and significant psychological stress[27]. The negative influence of the situation and the policy measures on the physical and mental health of people can be long-lasting[28]. However, multiple studies have found that contact with nature helped to cope with stress and supported individual well-being and resilience[29–33]. Particularly during lockdowns people sought nature experiences[27,34] and increased their visits to green areas and national parks if it was allowed[29,31,35–37]. All over the world people reported that urban green spaces became more important to them and their well-being[31,38,39], particularly if they didn't own private gardens[35]. However, socioeconomic attributes such as education or

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employment situation and different policy measures influenced the accessibility of green spaces[31,40]. Some people decreased their visits to urban green areas due to concerns about COVID-19 and overcrowding[38]. The studies indicate that safe access to high-quality urban green spaces should be one main strategy in times of crisis to buffer for the stressful situation[35,41].

In addition to an increase in overall urban green space use, a global "gardening boom" was reported at the beginning of COVID-19[42–44]. When many other forms of activities were restricted during the pandemic, gardening outdoors could be practiced safely allowing distance from others[45]. Similar to other urban green spaces, urban gardening creates multiple well-being benefits, and it helped people to cope with stress, social isolation, and anxiety[45–49]. Gardeners reported that they experienced gardening as a refuge from the stressful situation[44,50], and gardening was positively connected to higher well-being, positive emotions, and an increase in mental resilience[47,51]. However, gardeners also reported new barriers to urban gardening such as a lack of supplies and overcrowding in urban space[42]. Urban gardening can increase community adaptability and resilience by strengthening informal networks, creating social capital, and enabling collective learning[3,5,52,53]. In addition, gardening smooths the risk of food insecurity in urban areas by allowing access to nutritious food such as vegetables and fruits[9,46,54]. In the beginning of the pandemic, urban gardening became highlighted when other forms to maintain resilience and recreate were prohibited[55]. Sports facilities, cultural venues, many workplaces, and different social gatherings were closed which challenged or even prevented people from for example maintaining their physical health and income, experience culture and learn, and socialize. However, there is a lack of evidence on how exactly the benefits received from urban gardening changed compared to before the pandemic as well as in the long term after the initial lockdowns. Furthermore, it is not well understood whether pandemic-related changes in attitudes towards urban gardening indeed are also coupled with actions.

Here, we study urban box gardening in the city of Turku in Finland where the boxes are located on public land. Box gardening in Turku is an example of a public urban green space and urban gardening and some groups have characteristics of urban green commons[12]. This is because the resource (boxes and cultivations) is sometimes shared within a group of gardeners, presenting a form of collective management. The collective management is looser than for example in allotment gardens but there are groups of up to 15 people sharing boxes and working together[8], probably forming a different type of activity than individual gardeners. Box gardening has become a popular activity, whereby people can actively influence the availability and quality of urban green space in their vicinity[8,56]. It has not yet been widely studied[56,57]. The amount of urban green space is quite high in Northern Europe and Turku and its importance is increasingly acknowledged[40]. However, not only the quantity of green space but also its quality was important for pandemic resilience[40,41]. Urban garden boxes have the potential to increase the quality and nature richness even in small green areas such as pocket parks[56,58]. They can be located almost anywhere at a low cost, and make diverse green spaces more accessible in dense urban areas[32]. Small-scale urban gardening can be a quick solution to increase resilience in cities[53,58] but more knowledge is needed about its potential[14]. The importance urban green spaces have for resilience highlights the need for information about the influence a large-scale societal change such as the COVID-19 pandemic has on the sustainability of the social and ecological outcomes from them[20,57,59].

Here, we study box gardening before the pandemic (2019), during the first summer (2020), as well as in the long term when the political measures for social distancing were loosened (2021). Few previous studies analyze the influence of the pandemic on urban gardening and if the increased use continued even after the restrictions were eased[37,39]. Our sample population consists of urban box gardeners in Turku which is a subset of people interested and even committed to gardening, and therefore not representative of the whole population. However, the sample population offers us an opportunity to explore how gardeners' perceptions and the activity change after a disturbance as a measure of individual resilience. We investigate whether the importance the urban gardeners assign to gardening increases due to the pandemic, as found in other studies[35,42,44,45]. In addition, we investigate whether the cultivations and their success (ecological outcomes) or the gardeners' self-perceived outcomes change in 2020 and 2021 compared to the year 2019. We explore the outcomes of box gardening from the perspective of the Social-ecological Systems (SES) framework[20,59] which is a comprehensive analytical framework developed to analyze sustainability of SESs. The SES framework highlights the connection between social and ecological outcomes in reaching their sustainability. However, in higher-income regions, such as Finland, the social and well-being benefits and beautification are often more important than the yield or economic benefits from urban gardening[51,56,60,61]. Since it has been found that people had more time to garden and gave higher importance to gardening during the pandemic[42], we expect that both the ecological and self-perceived outcomes increased during the pandemic.

Results

Questions related to the COVID-19 pandemic

We find that in 2020 about 20% and in 2021 about 30% of the questionnaire respondents report some attitude changes toward gardening due to the pandemic (Fig. 1). The reported changes are almost entirely positive, meaning that the gardeners consider gardening either to be more important or have started gardening because of the situation. In 2020, 28 out of 139 respondents changed their attitude, and the change was negative for 1 respondent and positive for 27 respondents. In 2021, 44 out of 145 respondents changed their attitude, and the change was negative for 2 respondents and positive for 42 respondents. The two-tailed binomial probability for the attitude change in 2020 assuming that the direction of change is random is $p < 0.001$ and in 2021 $p < 0.001$. Therefore, for gardeners who reported attitude change, the attitude is significantly more positive towards gardening in both years. In addition, it seems that there were slightly more gardeners who reported positive attitude change in 2021 than in 2020.

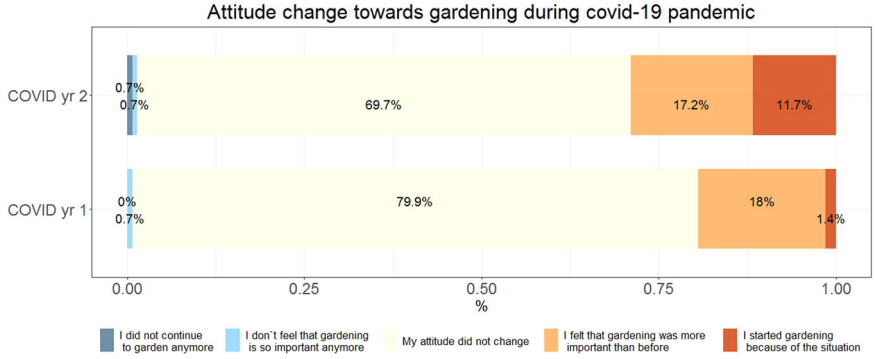

Fig. 1 | Attitude changes due to COVID-19. In COVID year 1 (2020) about 20% and in COVID year 2 (2021) about 30% of the respondents reported that their attitude toward box gardening has changed due to the COVID-19 pandemic. In both years, negative changes in attitude are rare (<2%). The two-tailed binomial probability test shows that the change in attitude is significantly more positive toward gardening in both years ($p < 0.001$).

We find that both in 2020 and 2021 about 20% of the respondents report some changes in their economic situation due to the pandemic (Fig. 2). In 2020, 30 out of 139 respondents reported a change in their economic situation, and for 5 of them the change was positive and for 25 of them the change was negative. In 2021, 28 out of 155 respondents reported a change in their economic situation, and for 7 of them the change was positive and for 21 of them the change was negative. The two-tailed binomial probability for the change in economic situation in 2020 assuming that the direction of change is random is $p < 0.001$ and in 2021 $p = 0.013$. Therefore, for gardeners who reported a change in their economic situation, the change is significantly more negative due to the pandemic. However, in 2021 fewer gardeners report that their economic situation is worse than in 2020. In addition, we investigated the change in attitudes and in economic situation for a limited sample of 54 gardeners (about 40% of the respondents) who answered the questions in both years and found out that the results are qualitatively the same (Supplementary Figs. 5 and 6).

The ecological outcome variables

Overall, we find two meaningful principal components for the ecological outcome variables with eigenvalues over 1 (Supplementary Table 6). Component 1 explains about 38% of the variance and Component 2 explains about 17% of the variance. In component 1 higher values mean that gardeners have a lower area of weeds and more other variables, especially more species, larger area of cultivations, and higher economic value (Table 1 and Fig. 3). The component 1 is named here an "Overall ecological outcome". In component 2, high values mean that gardeners have a high quality of produce and fewer species and individuals. In other way, this signifies that when gardeners cultivate a large number of individuals and species they tend to have lower quality of the overall produce. The component 2 is named here a "Simpler strategy for quality".

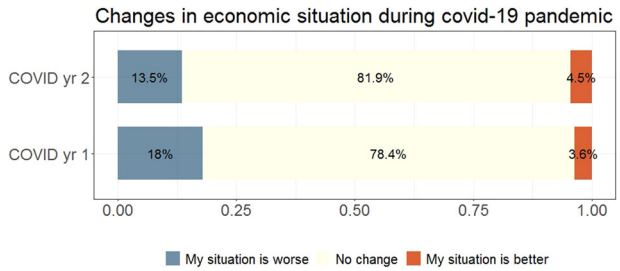

Fig. 2 | Changes in economic situation due to COVID-19. In COVID year 1 (2020) as well as in COVID year 2 (2021) about 20% of the respondents reported a positive or negative change in their economic situation due to the pandemic. A two-tailed binomial probability test shows that the change in the economic situation is significantly more negative than positive in both years (2020: $p < 0.001$, 2021: $p = 0.013$).

We find no significant difference between the year 2019 compared to the years 2020 and 2021 in "Overall ecological outcome" (2020: df = 90.9, $t = 0.181$, $p = 0.857$, 2021: df = 108.2, $t = 0.114$, $p = 0.909$) (Fig. 4). However, the general linear mixed model results show that the less years the gardener has gardened (df = 194.2, $t = 5.600$, $p < 0.001$) and the less sunny the location is (df = 202.8, $t = -2.137$, $p = 0.034$), the higher the ecological outcome is (Supplementary Table 7). The difference between the years 2020 and 2021 was investigated in a separate, otherwise identical model and no significant difference was found between the years (df = 114.7, $t = 0.054$, $p = 0.957$).

We find a significant difference between the year 2019 compared to 2020 (df = 143.01, $t = 4.646$, $p < 0.001$) and 2021 (df = 163.44, $t = 2.754$, $p = 0.007$) in "Simpler strategy for quality" (Fig. 4, Supplementary Table 8). In 2019 gardeners have a lower quality of produce but more species and individuals than in 2020 and 2021. The difference between the years 2020 and 2021 was investigated in a separate, otherwise identical model and no significant difference was found between the years (df = 165.5, $t = 1.661$, $p = 0.099$).

The self-perceived outcome variables

Overall, we find three meaningful principal components for the self-perceived outcome variables (Supplementary Table 9). Component 1 explains about 34% of the variance, Component 2 about 9% of the variance, and Component 3 about 9% of the variance. Component 4 has a higher than 1 eigenvalue but it is not meaningful considering the variable contributions, and therefore it is not included in the models. In component 1 lower values mean that gardeners receive less of all the listed benefits and higher values mean that gardeners receive more of all the listed benefits (Table 2 and Fig. 5). The component 1 is named here an "Overall self-perceived outcome". In component 2 the higher values mean that gardeners receive more social and non-tangible benefits such as beautifying the neighborhood and community feeling, and the lower values mean that gardeners receive more benefits related to the cultivations such as fresh vegetables and self-sufficiency. The second component is named here "High social, low practical outcomes". In component 3 the higher values mean that gardeners receive more family-related benefits such as educating their children or quality time with family and friends and the lower values mean that gardeners receive more individual-related benefits, such as physical exercise, new friends, and community feeling. The third component is named here a "High family, low individual outcomes".

We find a significant difference between the years 2019 and 2021 in Component 1 "Overall self-perceived outcome" (df = 130.2, $t = -2.468$, $p = 0.015$) (Fig. 6). In 2021 gardeners received fewer benefits than in 2019. Also, it seems that there is a decreasing trend in 2020 compared to 2019 (df = 108.4, $t = -1.021$, $p = 0.309$). In addition, the model results show that the more frequently gardeners meet (df = 201.5, $t = 2.074$, $p = 0.039$) and the sunnier the location is (df = 204.1, $t = 2.191$, $p = 0.030$) the higher the self-perceived outcome is (Supplementary Table 10). The difference between the years 2020 and 2021 was

Table 1 | The ecological outcome variable contributions to the components in the PCA

Variable	Component 1: "Overall ecological outcome"	Component 2: "Simpler strategy for quality"	Component 3	Component 4	Component 5
Quality	**0.40**	**0.74**	0.10	−0.45	0.28
Weeds	**−0.47**	**0.12**	0.79	0.32	0.18
Species	**0.71**	**−0.36**	−0.03	0.26	0.46
Area	**0.79**	**0.18**	−0.07	0.34	0.03
Economic	**0.74**	**0.17**	0.30	0.17	−0.49
Individuals	**0.46**	**−0.53**	0.41	-0.56	−0.03

Components 1 and 2 are included in the subsequent models (their values are marked in bold). Component 1 is named an "Overall ecological outcome" because the area of weeds has a negative contribution while all the other variables, which are beneficial for the outcome, have a positive contribution. Component 2 is named a "Simpler strategy for quality" because particularly higher quality has a positive contribution while a number of species and individuals have negative contributions.

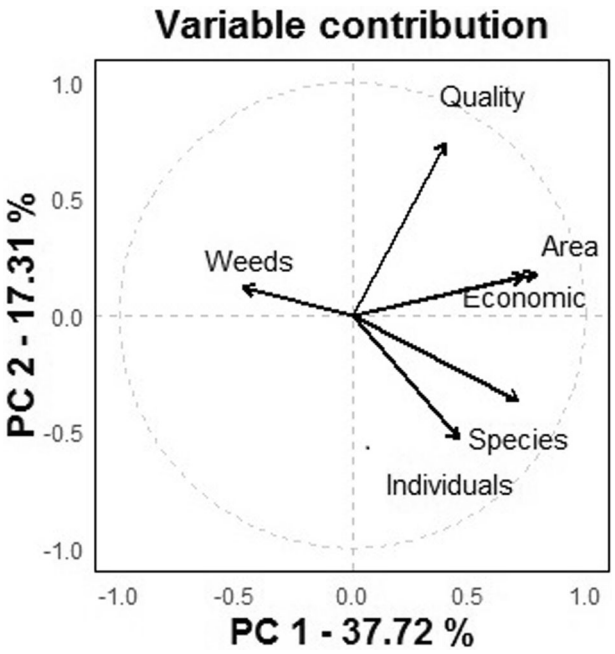

Fig. 3 | Variable contributions for Ecological outcome variables. Variable contributions presented visually for the ecological outcome variables for the Principal Components 1 "Overall ecological outcome" and 2 "Simpler strategy for quality".

investigated in a separate, otherwise identical model and no significant difference was found (df = 135.0, $t = 1.472$, $p = 0.143$).

We find a significant difference between the years 2019 and 2021 in Component 2 "High social, low practical outcomes" (2021: df = 168.29, $t = 2.179$, $p = 0.031$, 2020: df = 146.97, $t = 0.820$, $p = 0.413$). In 2019 gardeners reported to receive more practical outcomes and less social outcomes than in 2021. The general linear mixed model results show that the larger the group size (df = 202.55, $t = 3.427$, $p < 0.001$) and the less years gardener has gardened (df = 191.62, $t = 2.533$, $p = 0.012$) the higher the social and lower the practical outcomes are (Supplementary Table 11). The difference between the years 2020 and 2021 was investigated in a separate, otherwise identical model and no significant difference was found between the years (df = 169.40, $t = -1.368$, $p = 0.173$).

We find no significant difference between the years 2019, 2020, or 2021 in Component 3 "High family, low individual outcomes" (2020: df = 125.87, $t = -0.377$, $p = 0.707$, 2021: df = 145.47, $t = -0.470$, $p = 0.640$). The general linear mixed model results show that if the respondent gardened with family members (df = 203.39, $t = 2.171$, $p = 0.031$), the more frequently the gardeners met each other during the summer (df = 202.10, $t = 3.768$, $p < 0.001$), and the more public the box location was (df = 203.87, $t = -1.997$, $p = 0.047$) the higher the family and lower the individual outcomes are (Supplementary Table 12). The difference between the years 2020 and 2021 was investigated in a separate, otherwise identical model and no significant difference was found between the years (df = 149.79, $t = 0.110$, $p = 0.913$).

The data collection was based on the SES framework[20], and the changes in the Social, Economic, and Political settings due to the COVID-19 pandemic were expected to influence the entire garden box social-ecological system and self-perceived and ecological outcomes. Therefore, we have created a schematic diagram to summarize changes in the system and the variables during the study years presented within the SES framework (Supplementary Fig. 7).

Discussion

We studied how the COVID-19 pandemic influenced a Social-Ecological System - box gardening activity - in the city of Turku in Finland. Box gardening can be one way to support individual and community resilience by offering possibilities for social interaction and accessible small-scale green space close to people[36,48,58]. We find that when gardeners reported attitude change towards gardening because of the pandemic, the change was almost entirely positive. However, we find evidence that the outcomes gardeners self-perceive to receive from the activity decrease when compared to before COVID-19. Our results also show that in 2021 gardeners receive more social and less practical outcomes unlike before the pandemic. The overall ecological outcome did not differ between the years, but during the pandemic, the cultivations had higher quality and fewer species and individuals than in 2019. It seems that gardeners remain motivated to take care of cultivations and also assign a higher general importance to the activity, but – paradoxically – report to receive fewer outcomes from it. By comparing the activity before, during, and towards the end of the pandemic, we offer valuable knowledge on how public urban gardens and the resilience they create are influenced by large-scale societal change[20,40]. Even a small-scale system and its outcomes are significantly influenced by wide societal disturbance as the SES framework predicts[20,59] (Supplementary Fig. 7).

Adaptative change in individuals within a system can lead to a beneficial transformation increasing its sustainability[1,3]. We find several signs of long-term adaptation or even transformative change in the urban gardening Social-Ecological System due to the COVID-19 pandemic[2,53]. The positive change in attitudes increased, the applications for new boxes multiplied, and changes in self-reported outcomes and gardening strategy remained in 2021 compared to the beginning of the pandemic in 2020. The gardeners and the gardening community show ability to change or even transform which could lead to larger societal change increasing resilience towards future disturbances[2]. Urban programs where collective action is enabled and encouraged can function as hubs for social and sustainable transformation. However, the possible transformational change should be verified after the disturbance.

Based on our results, it is clear that for those who changed their attitude towards box gardening due to COVID-19, the direction is significantly towards being more positive. Nevertheless, a sizeable fraction of respondents reported feeling the same. A positive change in attitudes during the pandemic towards "green activities" is widely acknowledged, and generally, urban gardeners gave higher value to gardening and felt that it helped them to cope with the stressful situation[42,44,45,51]. Urban green spaces overall became more important to people[31,38,39,62], and particularly to people without private gardens[35]. However, previous research has mainly focused on the immediate changes in attitudes at the start of the pandemic in the spring 2020[62]. Our result suggests that the positive attitude change continues in the long-term in the pandemic conditions, even under less strict regulations[62]. The higher importance given to gardening amidst the pandemic indicates that box gardening is important for individual resilience[8,9,11].

The majority of the gardeners, 80% in 2020 and 70% in 2021 did not report a change in their attitudes towards gardening because of COVID-19. In other studies, the share of respondents changing their attitudes toward the importance or use of green spaces varies widely, between 20%[36] and 80%[31], depending on the question. One possible explanation for respondents not reporting a change in their attitude is that gardeners already give high value to box gardening regardless of the pandemic[36,42]. Furthermore, respondents were often successful in box gardening and therefore already highly motivated and committed. We also find that about 20% of the respondents report a change in their economic situation due to the pandemic, and the change was almost entirely negative. Urban gardening may offer one resilience tool to provide additional food and to cope with the mental well-being challenges a worse economic situation may pose[16,17,47,63].

We find, against our expectations, that the overall self-perceived outcome is lower in 2021 than in 2019 and shows a decreasing trend also in 2020. The finding suggests that the COVID-19 pandemic had a negative influence on the benefits the gardeners seek from urban gardening rather than strengthening them as assumed[43]. However, the objective well-being benefits are not measured[61]. There are several possibilities for the discovered decrease. Firstly, the boxes are located in public places, which might cause concerns about the lack of social distancing decreasing the benefits[38,40,42]. This is supported by the finding that frequently meeting other gardeners is

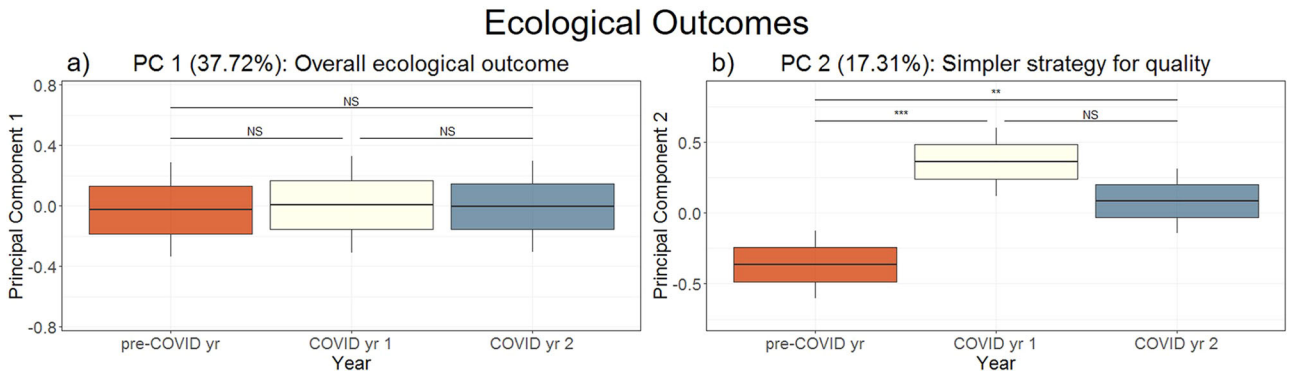

Fig. 4 | Differences between the years in the Ecological Outcomes. The differences in the (**a**) "Overall ecological outcome" and (**b**) "Simpler strategy for quality" between the pre-COVID year (2019), COVID year 1 (2020), and COVID year 2 (2021). The values are the mean, their standard error, and 95% confidence intervals extracted from the model outputs. Therefore, they include all the other variables included in the models controlling for the results. There is no significant difference between the years in "Overall ecological outcome" (marked NS), but there is a significant difference between the pre-COVID year and COVID years 1 and 2 in "Simpler strategy for quality" ($p < 0.001$ marked ***, $p < 0.01$ marked **, and non-significance marked NS).

Table 2 | The self-perceived outcome variable contributions to the components in the PCA

Variable	Component 1: "Overall self-perceived outcome	Component 2: "High social, low practical outcomes"	Component 3: "High family, low individual outcomes"	Component 4	Component 5
Fresh veg.	**0.54**	**−0.49**	**−0.05**	0.43	0.04
Physical	**0.52**	**0.07**	**−0.43**	0.14	0.43
Mental	**0.65**	**−0.11**	**−0.19**	−0.29	0.30
Beautify	**0.60**	**0.43**	**0.02**	−0.18	0.25
Educate	**0.33**	**0.19**	**0.74**	0.22	0.14
Self-sufficiency	**0.55**	**−0.54**	**−0.09**	0.32	−0.10
Friends	**0.52**	**0.35**	**−0.24**	0.42	−0.20
Community	**0.59**	**0.47**	**−0.27**	0.24	−0.11
Quality time	**0.55**	**0.11**	**0.54**	0.26	0.12
Knowhow	**0.50**	**−0.27**	**0.19**	−0.27	−0.02
Happiness	**0.71**	**−0.19**	**0.01**	−0.14	0.21
Social movement	**0.62**	**0.07**	**0.01**	−0.05	−0.57
Nature	**0.73**	**−0.20**	**0.05**	−0.36	−0.25
Biodiversity	**0.65**	**0.21**	**0.01**	−0.37	−0.12

Components 1, 2, and 3 are included in the subsequent models (their values are marked in bold). Component 1 describes an "Overall self-perceived outcome" with a positive contribution from all the benefits assessed by the gardeners. Component 2 describes a "High social, low practical outcomes" and Component 3 describes a "High family, low individual outcomes".

connected with more self-perceived outcomes. A second possible reason is that even though gardening can be positively connected to higher well-being and positive emotions during the pandemic[47,51], all these aspects can still decrease when compared to before the pandemic. The negative influence the pandemic and the policy measures overall had on the physical and mental health of people might extend to the gardening activity[28]. Since our study does not compare the gardeners and non-gardeners in Turku, we are unable to say if the gardening activity improved well-being during the pandemic. However, it is known that urban green spaces and gardening particularly had a positive influence on mental and physical health, mental resilience, and social interactions during COVID-19[16,17,29,47–49]. In addition, our study considers the long-term influence of the pandemic after the initial lockdowns, unlike much previous work[27,34,35]. The finding suggests that the negative influence of the pandemic is long-lasting or even transformative[52]. Thirdly, when gardeners placed higher importance on gardening and had more free time, they might have placed higher expectations on the gardening activity. Higher expectations can lead to lower estimation of the received benefits than before the pandemic. We find also differences in the type of outcomes received, and in 2021, compared to before COVID-19, gardeners estimated to receive more social and less practical benefits. The finding suggests that the motivational effect of social interactions might be strengthened due to a disturbance and gardeners emphasize the social and nonmaterial sides of gardening[44,60]. Social outcomes were increased in larger groups, which presumably share a more social setting presenting characteristics of urban green commons[8]. The findings suggest that box gardening can positively influence community resilience by, for example, strengthening social networks in the form of higher community feeling and new friends[7]. In addition, the resilience provided by the activity could be strengthened if it were developed towards urban green commons. Urban green commons can build resilience through community empowerment, social and cultural integration and diversity, and enabling social and ecological learning[8,12]. However, a deeper investigation of the group dynamics would help understand the underlying factors influencing the outcomes.

We find that the COVID-19 pandemic did not influence the overall ecological outcomes received from box gardening. Regardless of the changes in attitudes and conditions, people remain motivated to create local biodiversity and produce for themselves similarly to before the pandemic[18]. Other variables, such as the starting year and the box location proved to be more important. The finding suggests that the influence small-scale urban gardens have on local biodiversity stays

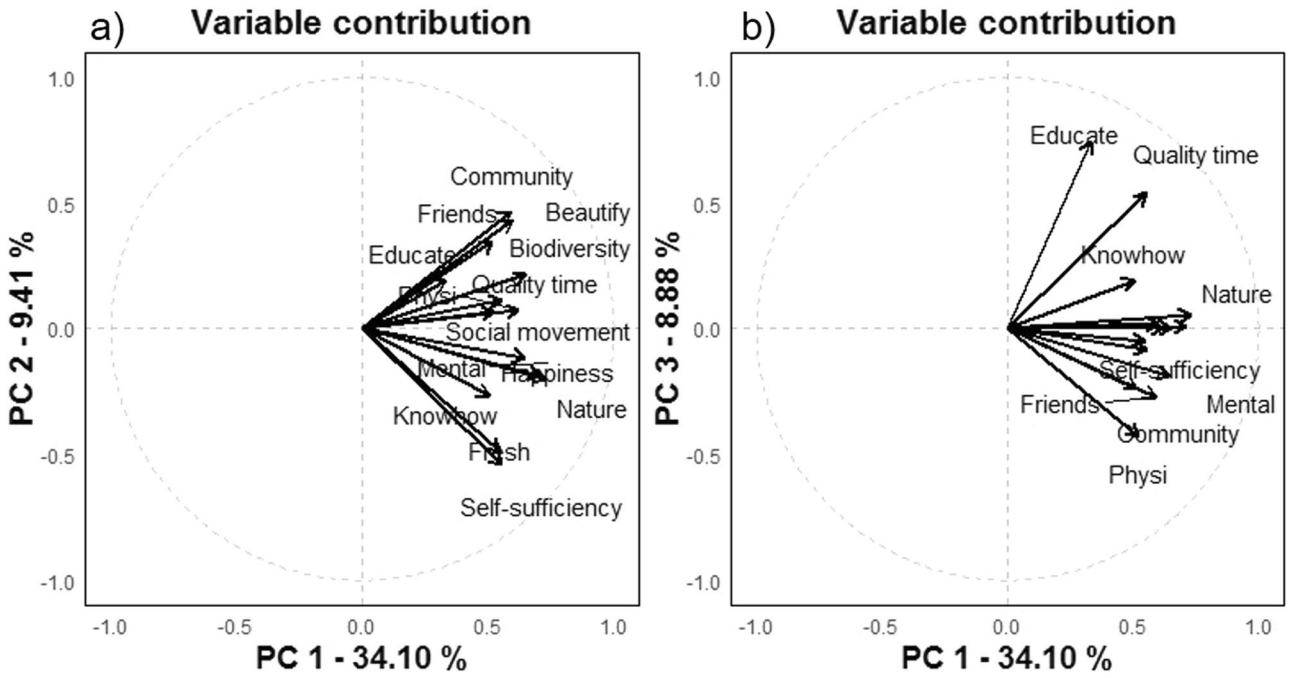

Fig. 5 | Variable contributions for the Self-perceived outcome variables. Variable contributions presented visually for the self-perceived outcome variables for the (**a**) Principal Components 1 "Overall self-perceived outcome", and 2 "High social, low practical outcomes", and (**b**) 3 "High family, low individual outcomes". Due to the large number of variables, the names overlap with the arrows and not all of the names are included in the figure for principal components 1 and 3.

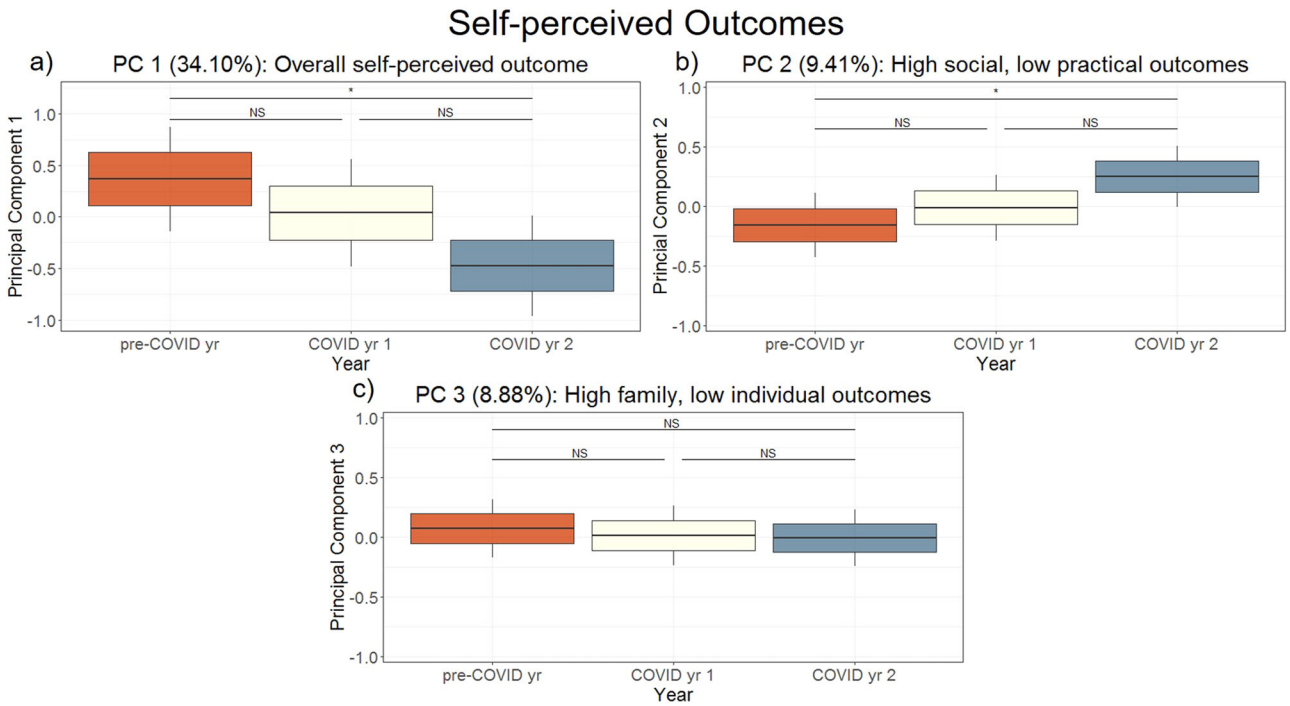

Fig. 6 | Differences between the years in the Self-perceived Outcomes. The differences in the (**a**) "Overall self-perceived outcome", (**b**) "High social, low practical outcomes", and (**c**) "High family, low individual outcomes" between the pre-COVID year (2019), COVID year 1 (2020), and COVID year 2 (2021). The values are the mean, their standard error, and 95% confidence intervals extracted from the model outputs. Therefore, they include all the other variables included in the models controlling for the results. There is a significant difference between the pre-COVID year and COVID year 2 in "Overall self-perceived outcome" and "High social, low practical outcomes" (non-significance marked NS and $p < 0.05$ marked *).

stable during a disturbance caused by the pandemic[56,58]. Against the expectations based on the increase in importance, outdoor recreation, and free time[39,42,64], the ecological outcomes did not increase during the pandemic. However, to our knowledge, the long-term influence on ecological outcomes has not been studied before[42,45]. We do find that before the pandemic, gardeners had a lower quality of cultivations, but managed to grow more species and individuals per garden box than during the pandemic. The second principal component demonstrates

that a simple strategy with fewer species and individuals, possibly with similar requirements, is connected to a higher overall quality. The detected change might indicate that during the pandemic some gardeners did look after the cultivations better by becoming more focused on fewer species and individuals. In another study, gardeners changed their gardening habits to be more innovative with new techniques and plants during the pandemic[42]. In addition, lack of gardening supplies during the pandemic "gardening boom" could have led to simpler gardening strategies. Our divergent findings for the self-perceived and ecological outcomes support their disconnection, as found before[56]. It is possible that the self-perceived outcomes were more influenced by the COVID-19 pandemic than the ecological ones because people gave higher importance to the non-material values than the material ones[44]. Even though, in a small-scale Social-Ecological System such as box gardening the more social and non-material outcomes are emphasized in the individual or community resilience[8,10], the physical resource is needed for their emergence.

People experienced the COVID-19 pandemic and related lockdowns differently[29]. Possibly because of the higher mental burden from the situation, particularly women, young people, and families with children increased the use of public urban green spaces, such as gardening[40,64]. A limitation of our study is the lack of information about the socioeconomic attributes of the gardeners over the years. In 2021 the information was collected and we found that the respondents are often women, young adults, and educated. The garden box program is available for all citizens, but socioeconomic attributes may influence the benefits received[31,38]. The quality of the green space where the boxes are placed in different areas can vary and wealthier areas often have more beneficial and safer spaces[14,34]. However, in Turku, the areal economic differences are moderate[65]. In the future, the program could benefit from registering the socioeconomic attributes of the participants and additional efforts to offer benefits and resilience from the activity for different areas and gardeners with different needs[4,30,33]. Urban box gardening programs can work as one resilience tool for a certain group of citizens but a set of different well-functioning programs is needed to develop the resilience of the city.

The COVID-19 pandemic has made it clear that access to urban green spaces supports mental and physical well-being during stressful situations and disturbances[62,66,67]. The increased importance given to box gardening indicates that the activity promotes gardeners' individual resilience[8,9,11]. However, the undeniably negative influence of COVID-19 on well-being seems to extend to the benefits received from gardening[28]. Our results suggest a shift during the pandemic from practical outcomes towards an emphasis on social benefits from the activity, and the resilience of the system could be increased if the activity would be developed towards urban green commons. In addition, we find that the pandemic influenced gardening strategies but the gardeners remained motivated to produce overall ecological outcomes similar to before. Therefore, we conclude that the sustainability of the outcomes from a small-scale Social-Ecological System such as box gardening is influenced by changes in the wider societal settings[20,57,59]. Not only pandemics but other large societal changes such as climate change will challenge individual, community, and systemic resilience in the future[3–5]. Therefore, there is a need to better prepare for similar situations and the most important benefits from public urban gardening programs should be secured in times of crisis. Based on our findings, we support the previous statements that urban green spaces should remain open and accessible during pandemic restrictions[35,40]. Box gardening can offer positive benefits and resilience for others than just the gardeners, such as friends, families, and passers-by[5,14]. However, mechanisms such as participatory planning could assist in recognizing different needs and maintaining the received benefits in times of disturbance[23,31,64]. A comparison of the activity before the pandemic, in the first year, and over a year after the initial lockdowns offers valuable insight into the changes in the system. Our results suggest that the influence of the pandemic continues and might even strengthen in the long term.

Methods

Background

The study was performed during the summers of 2019, 2020, and 2021 in the medium-sized city of Turku in Southern Finland. The city has an urban gardening program where one or more garden boxes (each 1 m^2 in size) and soil are provided for free for people who enroll in the program. The gardeners self-organize their gardening groups and cultivations and they can choose the location of the boxes, as long as the box is on public land. In 2019 there were 698 garden boxes in 245 locations, in 2020 674 garden boxes in 243 locations, and in 2021 762 garden boxes in 297 locations (Supplementary Fig. 1). The boxes are located everywhere around the Turku city area. The program is popular and even though the city provides new boxes every year, the interest is higher than the supply of the boxes. In 2019 there were 116 applications and 70 new boxes were provided, in 2020 46 applications and 40 new boxes, and in 2021 171 applications and 110 new boxes.

Data collection

Urban box gardening is a small-scale Social-Ecological System where the physical resource is the cultivations (what grows in the box). The data collection was based on the SES framework to identify potentially relevant variables influencing the outcomes of box gardening at a resource user (gardener) level (Supplementary Table 1)[20,59]. The framework is comprehensive and designed to combine the social and ecological parts of a resource system, and it emphasizes the role of resource users which is the focus of our study. Data was collected by field inventories to objectively measure the ecological outcome, i.e., what grows in the boxes, and by electronic questionnaires to measure the self-perceived outcome and characteristics of the gardeners. We have labeled the 14 different and diverse benefits potentially received from gardening and self-assessed by gardeners as self-perceived outcomes[20] (Supplementary Table 2 and Supplementary Fig. 2). Field inventories were performed each year three times per summer five weeks apart (June, July, and September) on all the urban gardening boxes in all locations. The three visits are sufficient to capture the short growing season of Finland. The average values of the three inventories are used in the analyses to consider differences in the gardening effort and success over the summer as a whole. To assess the ecological outcome, cultivated species were identified, the number of cultivated individuals belonging to different species was estimated, the quality of each species and their area cover in the box was evaluated, and the area covered by weeds was estimated. The economic value of cultivations per box for each gardener or gardening group was estimated for cultivated species (procedure developed by Tuominen et al.[56]). We acknowledge that the weed species richness does influence the local biodiversity, but since it does not describe the cultivation success, the information is not included in the study. In addition, we recorded if the box was located more secluded or not (privacy) and the boxes' average exposure to the sun (shade) (Supplementary Table 2).

Every year gardeners were asked to fill out two electronic questionnaires, one before the growing season and one after the season (Webropol 3.0 online surveys). The questionnaire at the end of the season contained questions considering the self-perceived outcome, i.e., 14 different benefits potentially received from the activity[17,49,56]. The gardeners assessed for each benefit if they did not receive it, received it a little, or received it a lot during the summer. In addition, the questionnaire collected information characterizing the gardeners and the activities (group size, family members in the group, frequency of group meetings, number of other gardeners in the location, starting year, and number of gardening boxes) (Supplementary Fig. 3). In 2020 and 2021 the questionnaires included questions considering the COVID-19 pandemic (Supplementary Fig. 4). Briefly, respondents were asked whether the COVID-19 pandemic has caused changes in their gardening, their attitude toward gardening, or their economic situation. The answers to the questions are combined in the results from both before and after the season questionnaires, excluding

accidental double answers from some respondents. Each respondent was asked to provide the name of the gardening group that they used in reporting to the city, and that was written on a sign in their boxes. This enabled us to connect the information collected from the field to the otherwise anonymous questionnaire data. The responses from the after-season questionnaire are used in the analyses, which resulted in a sample size of 216 gardeners for the analyses (2019:67, 2020:65, 2021:84). Each year we were unable to connect few survey respondents to the field data (incorrect name provided), and therefore the sample size is slightly lower than the number of after-season survey respondents reported next.

To collect the questionnaire data, the participants in the program were contacted by e-mail through the city's gardener registry by the city of Turku. In addition, the questionnaire was advertised on the program's Facebook page and by distributing a small information card at each box with a link to the questionnaire. Informed consent was obtained from all participants when they submitted the information and agreed to participate in the project. Some of the gardening locations (785 all three years) consist of several "sub-groups", which answered our survey separately. Therefore, we have altogether 822 gardening locations in the dataset. In all years combined 420 respondents answered the surveys out of 822 gardening locations (51.1% response rate) and 234 gardeners responded to the after-season questionnaire (response rate 28.4%). We received in 2019 73/256 responses (28.5%), in 2020 69/258 responses (26.7%), and in 2021 92/308 responses (29.9%). We acknowledge that since the mean gardening group size is 2.36 for the respondents, the response rates could be changed from the ones based on the locations but we had no possibility to control for this. According to conventional wisdom, which is based on the field reports of major survey companies in Finland, response rates are commonly as low as 10 percent in comparable survey designs. In comparison, then, our response rate was relatively high in the Finnish context[68]. In addition, the after-season survey respondents do not show any geographic clustering (Supplementary Fig. 1). Unfortunately, the representability of the data used in the analyses cannot be fully explored because the city does not collect background data about the gardeners. We assume that the gardeners as a group do not represent the attributes of the population of Finland or Turku in general. We were able to assess the ecological outcomes in the field for the gardeners who did not respond to the questionnaire (non-respondents). We found that the respondents and non-respondents differ significantly from each other in 2019 in the amount of weeds and cultivated area and in 2020 and 2021 in all values ($p < 0.05$). Respondents have a produce in their box with a higher economic value, have fewer weeds per box, have a produce of higher quality, with more species per box, more individuals per box, and more cultivated area per box. However, based on the data from 2021 about 25% of non-respondents had quit gardening without reporting it to the municipality so that the boxes would be collected away. Therefore, even though it seems that the respondents might be more successful gardeners, the non-respondents who actually have quit gardening can impact the values significantly.

Further descriptions of the data and the respondents were investigated when possible (Supplementary Table 3). In 2020 and 2021, the education levels of the respondents were very similar: about 40% had a graduate degree, 25% undergraduate degree, 30% had a secondary education, and the rest had a primary school education. In 2021 almost 40% of the respondents belonged to the age group 30–39 and then were divided quite equally (15% in each) for the successive age groups until 70 years old. In addition, most respondents identified themselves as females (78%). The dataset consists of new gardeners as well as gardeners who have been gardening for several years (old gardeners). In the dataset used in the analyses, 87 were new gardeners out of 216 (40.3%), and the share was in 2019 41.8%, in 2020 21.5%, and in 2021 53.6%. When the response variables were explored separately for new and old gardeners they report similar self-perceived outcomes but differ significantly ($p < 0.01$) in ecological outcome variables. New gardeners perform higher quality produce and economic value, larger area of the cultivations, more species and individuals, and a lower share of the weeds. Therefore, we include in the analyses the year when box gardening was started.

Statistical analyses

First, we explored the questionnaire responses considering the self-assessed changes in attitudes towards gardening or in the economic situation due to the COVID-19 pandemic. We investigated by a binomial sign test if the reported changes in attitudes and the economic situation tend to be more positive or negative. The method calculates the two-tailed binomial probability for the responses assuming that the direction of change is random. In 2021 one additional option ("my interest in a more sustainable lifestyle has increased", $n = 29$) was included in the question about the attitude change towards gardening. The option was not considered to be directly related to gardening but rather described overall attitudes. Therefore, the responses to the option were removed from the analyses.

Second, we investigated the ecological and self-perceived outcome variables by a principal component analysis (PCA) in order to decrease the complexity of the dataset and explore the outcome patterns. We performed a PCA for the six ecological outcome variables and the 14 self-perceived outcome variables. The ecological outcome variables were the average quality of the produce, species per box, area of cultivations per box, individuals per box, the economic value of the cultivations per box, and share of weed cover per box (%). The self-perceived outcome variables were fresh vegetables, physical exercise, mental relaxation, beautify the area, educate children, self-sufficiency, new friends, community feeling in the neighborhood, quality time with friends and family, knowhow, happiness, belong to a social movement, nature experiences, and create biodiversity. Even though the SES framework emphasizes their connection, we performed here the analyses separately for the ecological and self-perceived outcome variables. Rationale for doing so comes from their disconnection in previous work[56] and weak correlations found in here (Supplementary Table 4).

Third, we explored by a general linear mixed model analysis if there are differences between the years 2019, 2020, and 2021 in the ecological outcomes or the self-perceived outcomes of the activity. The response variables in the models were the meaningful principal component scores computed for each gardener created by a PCA. A principal component was considered meaningful when the eigenvalue was over 1 and the variable contributions were sensibly describing an outcome. The explanatory variables were the focus variable, the year the data was collected, controlled by the gardening group size, family members in the group, frequency of group meetings, number of other gardeners, starting year, number of boxes, privacy, and shade (Supplementary Tables 1 and 2). The gardening group size considers whether the more social setting for urban gardening plays a role in its outcomes. Out of the sample population of 216, there were 80 individual gardeners (37%). Assumptions for the data were investigated and they were acceptable for models (Supplementary table 5). As several gardeners continue gardening over the years, a gardener ID was included as a random effect in all the linear mixed models. Analyses were performed in R by principal component analysis (package FactoMineR) and general linear mixed model (package lme4). The PCA scales the variables to unit their variance and therefore no data transformations were performed before the PCA.

Data availability

The relevant datasets used and/or analyzed during the current study are available from the corresponding author on a reasonable request.

Code availability

The relevant codes developed and used during the current study are available from the corresponding author on a reasonable request.

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Author contributions

All: conceptualization, methodology, validation; L.T.: formal analysis, investigation, data curation, writing – original draft; H.H.: writing – review & editing, funding acquisition; P.K.: writing – review & editing, funding acquisition; L.R.: writing – review & editing, funding acquisition; T.V.: writing – review & editing, funding acquisition; J.B.: writing – review & editing, supervision, project administration, funding acquisition.

Competing interests

The authors declare no competing interests.

Additional information

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