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Residential exposure to greenspace and life satisfaction in times of COVID-19: a cross-sectional analysis of 9444 participants from a population-based study in Basel-Stadt and Basel-Landschaft

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Summary

BACKGROUND: Subjective well-being is an important target in the COVID-19 pandemic. Residential greenness may help cope with stress and hence influence subjective well-being during this mentally and physically challenging time.

METHODS: We analysed the association between residential greenness and life satisfaction in 9,444 adults in the COVCO-Basel cohort. We assessed if the association is modified by age, sex, household income, financial worries, canton of residence, or month of study entry. In addition, we assessed if the association is attributed to specific types of greenspace or accessibility to greenspace.

RESULTS: The association between residential greenness and life satisfaction varied by age groups, household income, and financial worries. Residential greenness was positively associated with life satisfaction in those with high household income and the least financially worried, and negatively associated with life satisfaction in the youngest age group (18–29 years) and the most financially worried. Living closer to a forest, but not to a park or an agricultural area, was associated with lower life satisfaction in the youngest age group.

CONCLUSIONS: Residential greenness effects on life satisfaction vary according to sociodemographic characteristics. Living in a greener area does not benefit all dwellers in Basel and its region equally, with the most apparent benefit for those with high household income and without financial concerns.

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Introduction

What is the public health that we have been striving to protect during the COVID-19 pandemic? The World Health Organization (WHO) declared long ago that "health is a state of complete physical, mental and social well-being and not merely the absence of disease or infirmity". Efforts to prevent SARS-CoV-2 infections must therefore be partnered with efforts to maintain people's mental health and social well-being. The COVID-19 pandemic, including the epidemic itself and its containment measures, may have long-term significant consequences on mental health and well-being [1–3]. Acknowledging the importance of monitoring the citizens' well-being in assessment of long-term consequences of the COVID-19 pandemic, we initiated the COVCO-Basel cohort (population-based SARS-CoV-2 Cohort Basel-Landschaft and Basel-Stadt) [4]. It follows more than 10,000 residents of a random sample of the general adult population of the Swiss cantons Basel-Stadt and Basel-Landschaft to investigate their lifestyle, interactions with their living environment, mental health and well-being during (and after) the pandemic.

Subjective well-being has been associated with better overall health and increased life expectancy [5, 6]. Individual well-being is an important target to monitor, as an intermediate outcome, and as a goal in itself [7]. Individuals with high well-being show better productivity and creativity [8, 9], contributing to better functioning of a society. The proper functioning of a society serves as the foundation to successfully overcome challenges such as the COVID-19 pandemic.

The well-being of an individual is significantly influenced by the surrounding environmental conditions and circumstances [10]. Previous research reported beneficial effects of residential green on general health and well-being [11–13], with proposed pathways including improved air quality, physical activity, social cohesion, or coping with stress [14–17]. Especially during mentally and physically challenging times, the immediate greenspace environment can help mitigate the negative impacts by providing a recreational, freely accessible environmental resource that enables recovery from stressors, debilitation, fatigue, and social isolation [18, 19]. This study is the first attempt to investigate the residential greenness effects on subjective well-being during the COVID-19 pandemic, from a population-based sample in Switzerland.

The primary objective of this study was to assess whether residential greenness is associated with subjective well-being during the COVID-19 pandemic in the Basel region of Switzerland. We assessed a priori selected covariates to check if they modulate the greenness effects. As secondary objectives, we assessed if the greenness effects can be attributed to specific types of greenspace or accessibility to greenspace. By investigating the effect modulation and by differentiating various greenspace metrics, we hope to shed light on the mechanism behind the residential greenness effects on subjective well-being.

Methods

Study population

In this cross-sectional analysis, we analysed the baseline information from COVCO-Basel. COVCO-Basel is a digital cohort in North-Western Switzerland, specifically initiated to investigate the long-term impact of the COVID-19 containment measures on broad domains of health and well-being. A sub-cohort of COVCO-Basel also participated in the Corona Immunitas programme launched as a seroprevalence survey to assess the extent, nature, and duration of immunity against SARS-CoV-2 at the cantonal and the national level in Switzerland [20]. Any person aged 18 years or older residing in Basel-Stadt or Basel-Landschaft for at least 5 years was eligible. Random samples of eligible residents of the same size for both cantons (Basel-Stadt and Basel-Landschaft) and age strata (18–49, 50–65, 65+ years) were provided by the Federal Statistical Office. They are randomly assigned to two arms, i.e. a seroprevalence arm and a questionnaire-only based arm. Invitations were sent in waves, separately for the two arms. In the seroprevalence arm, 2,457 out of the 15,981 people who received the invitation participated at baseline. In the digital cohort arm, 10,111 out of the 96,867 invited participated at baseline. Out of the 9,629 digital cohort participants entering the cohort between July 2020 and March 2021, we analysed 9,444 participants with non-missing information on residential address, life satisfaction, and all covariates listed below. The COVCO-Basel study population is comparable to the total population in the two cantons in terms of available sociodemographic factors including gender and marital status, although women are overrepresented in age group <65 years and underrepresented in age group 65+ years. Foreigners are underrepresented as expected given that the questionnaires are only provided in German. The final report of the study including a detailed protocol (in German) is publicly available online [4].

The study protocol was approved by the regional ethics committee (Ethikkommission Nordwest- und Zentralschweiz 2020–00927) and all participants provided informed consent prior to enrolment to the study.

Life satisfaction

Self-reported life satisfaction can accurately summarise subjective well-being [21, 22]. Life satisfaction was assessed by the question "Overall, how satisfied are you with life as a whole these days?" on a scale from 0 (not satisfied at all) to 10 (completely satisfied) at the time point of recruitment [23]. At the same time, life satisfaction prior to COVID-19 was retrospectively assessed by the question "Overall, how satisfied were you with life as a whole before COVID-19?" on the same 0–10 scale.

Greenspace assessment

Three commonly accepted methods to evaluate greenspace exposure were applied to the participants.

Normalised difference vegetation index (NDVI)

NDVI is a satellite-based measure of general greenness, regardless of type or size of greenspace. It estimates the density of green, based on the difference between visible (VIS) and near-infrared (NIR) light reflected by vegetation [NDVI = (NIR – VIS)/(NIR + VIS)] [24]. NDVI values are from −1 to 1, where: <0.1 represents barren areas, sand or snow; 0.2–0.3 represents shrub and grassland; and values >0.3 indicate increasing intensity of green. For this analysis, we used an existing 30×30 m NDVI dataset constructed for Switzerland by Vienneau and her colleagues [25]. NDVI was derived from cloud- and snow-free satellite images collected during summer in 2014 (30×30 m resolution Landsat 8 scenes, from 08 June to 19 July 2014), and combined in a mosaic to obtain full coverage of Switzerland. The exposure modelling methods, including the exact Landsat 8 scenes comprising the mosaic, are described in full previously [25]. Mean NDVI within 100 m, 300 m, 500 m, and 1000 m "circular buffers" around participants' geocoded home address were calculated on the basis of this 30×30 m dataset for Switzerland.

Green land use: proportion of forest, park, and agricultural area

Proportion of area covered by either forest, urban parks, or agricultural area was computed within 100 m, 300 m, 500 m, and 1000 m circular buffers around participants' home address. We used the data on the land use from SwissTLM Regio (https://www.swisstopo.admin.ch/de/geodata/landscape/tlmregio.html) and the boundaries from SwissBOUNDARIES3D (https://www.swisstopo.admin.ch/de/geodata/landscape/boundaries3d.html).

Proximity to greenspace: route to forest, park, and agricultural area

As a better indicator of proximity to greenspace, we computed shortest route considering the road network, rather than Euclidian distance. Shortest route to either forest, ur-

ban parks, or agricultural area was computed for each participant's home address, based on the road network data from SwissTLM Regio (https://www.swisstopo.admin.ch/de/geodata/landscape/tlmregio.html).

Buffer selection

Given the high correlations between buffers, we applied the following approach to select the optimal buffer size for analysis. Beta regression of life satisfaction on the NDVI of each buffer, adjusted for life satisfaction in the past, age, sex, household income, financial worries, canton, degree of urbanisation, and month of entry, were compared. The 300 m buffer had the smallest Akaike information criterion (AIC) value and was thus selected. We used the same 300 m buffer for the land use variables.

Covariates

Covariates were selected according to a hypothesised framework by which greenspace may impact on life satisfaction (figure S1).

Self-reported age in years was classified into four categories, 18–29, 30–49, 50–65, and 65+ years. The recruitment was stratified by 18–49, 50–65, and 65+ years and we further stratified to have a better representation of participants below age 30. Gender (male/female/other) was self-reported. Non-binary gender group (other) was excluded due to its very small sample size. Self-reported household income was classified into three categories, below 6,000, 6,000–15,000, and 15,000+ CHF/month. Financial worries were determined by a question "How often do you worry about being able to meet normal monthly living expenses?" on a scale 0 (worry all the time) to 10 (do not ever worry) and classified into terciles. Canton of residence distinguished Basel-Stadt and Basel-Landschaft. Degree of urbanisation assessed by DEGURBA index (https://www.bfs.admin.ch/bfs/de/home/statistiken/kataloge-datenbanken/karten.assetdetail.13787277.html; https://ec.europa.eu/eurostat/web/degree-of-urbanisation/background) was classified into three levels, below 300, 300–1,500, and 1,500+ inhabitants/km^2. The month of entry was recorded as the time point of baseline questionnaire and dichotomised as T1 (July to October 2020) and T2 (November 2020 to March 2021). T2 was the period of more stringent COVID-19 containment measures.

Statistical analysis

Given the limited range of the life satisfaction measured on a scale from 0 to 10, we decided to apply Beta regression with logit link. For Beta regression, the life satisfaction was first divided by 10 and then regressed on greenspace after adjustment for life satisfaction in the past, age, sex, household income, financial worries, canton, degree of urbanisation, and month of entry.

The regression analysis was conducted in three steps:

Step 1. Life satisfaction was regressed on NDVI only, to examine the association of general greenness with life satisfaction. We tested both main association and moderations. For moderations, we assessed a priori selected covariates, i.e., age, sex, household income, financial worries, canton, and month of entry, applying likelihood ratio test. The main association and moderations were declared statistically significant if the p-value was below 0.05.

Step 2. In case of significant main association or moderations from Step 1, life satisfaction was regressed on the three land use variables instead of NDVI, to see if, and to which extent, any specific greenspace can explain the NDVI effect.

Step 3. In case of significant main association or moderations from Step 1, life satisfaction was regressed on the three route variables additionally adjusted for NDVI, to see if accessibility to specific types of greenspace matters, given the same amount of greenness.

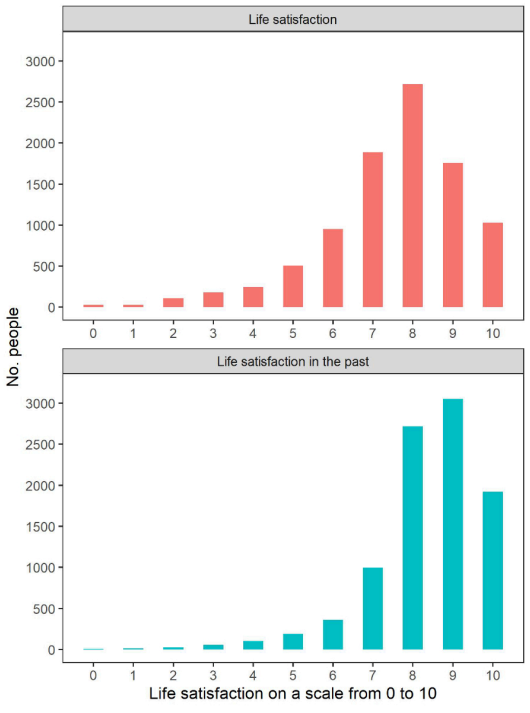
As a sensitivity analysis, we repeated the final models with ordered probit regression that better accommodates discrete nature of the life satisfaction.

All statistical analyses were conducted using R 4.0 [26]. We used the "betareg" function from the "betareg" package for Beta regression and the "polr" function from the "MASS" package for ordered probit regression. R code to produce the findings of this study is available at a public github repository (https://github.com/AyoungJEONG/COVCO-greenspace).

Results

Study population characteristics are summarised in table 1. About half of the participants lived in the canton of Basel-Landschaft which consists of periurban as well as rural areas. Basel-Stadt is a predominantly urban. Less than one third of participants reported a household income in the lowest category. About two thirds of participants entered the study after November 2020. Figures 1 and 2 visualise the distribution of life satisfaction and greenspace among the study population, respectively. The pairwise correla-

Figure 1: Histogram of life satisfaction in the study population (N=9444).



tion between greenspace variables is visualised in figure S2. NDVI was positively correlated with the percentage of forest as well as agricultural area in a buffer of 300 m, and with proximity to nearest park. It was inversely correlated with percentage of park in a buffer of 300 m, and with proximity to agricultural and forest greenspace.

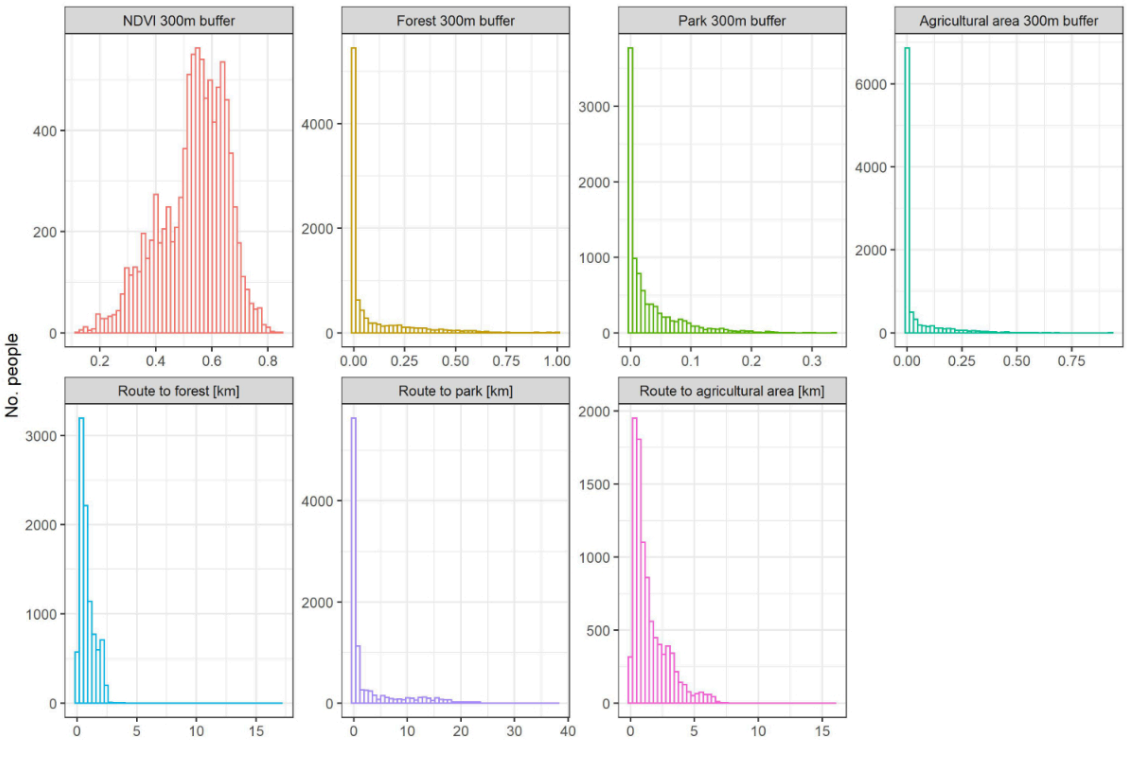
Table 1:
Baseline characteristics of COVCO-Basel participants.

		Total
N		9,444 (100%)
Age [years]		55.5 (15.1)
Sex	Female	5,072 (53.7%)
	Male	4,372 (46.3%)
Household income	<6,000 CHF/month	2,789 (29.5%)
	6,000–15,000 CHF/month	5,369 (56.9%)
	15,000+ CHF/month	1,286 (13.6%)
Financial worries*	0	283 (3.0%)
	1	129 (1.4%)
	2	213 (2.3%)
	3	216 (2.3%)
	4	204 (2.2%)
	5	390 (4.1%)
	6	369 (3.9%)
	7	655 (6.9%)
	8	1,341 (14.2%)
	9	1,991 (21.1%)
	10	3,653 (38.7%)
Canton	Basel-Stadt	4,770 (50.5%)
	Basel-Landschaft	4,674 (49.5%)
Degree of urbanization	<300 inhabitants/km^2	458 (4.8%)
	300–1,500 inhabitants/km^2	1,734 (18.4%)
	1,500+ inhabitants/km^2	7,252 (76.8%)
Month of entry	Jul 2020 – Oct 2020	3,112 (33.0%)
	Nov 2020 – Mar 2021	6,332 (67.0%)

Data presented as mean (standard deviation) or count (percentage).

* 0–10 scale from the question “How often do you worry about being able to meet normal monthly living expenses?”, where 0 means “worry all the time” and 10 “do not ever worry”.

Figure 2: Histogram of greenspace variables in the study population (N=9444).



We did not observe main association of NDVI on life satisfaction (table S1). However, we observed moderations by age, household income, and financial worries (likelihood ratio test p-values were 0.016, 0.0049, and 0.014, respectively). NDVI showed negative association with life satisfaction in the youngest age group (18–29 years) but not in the older groups (figure 3 and table 2), and positive association with life satisfaction in the participants with high household income (15,000 CHF per month or higher) but not in those with lower household income (figure 4 and table 3).

This NDVI effect in the high household income group corresponds to a life satisfaction increase by 0.2 points for NDVI increase from 1st to 3rd quartile. NDVI was negatively associated with life satisfaction in the most financially worried, while positively associated with life satisfaction in the least financially worried (figure 5 and table 4). When NDVI increased from 1st to 3rd quartile, life satisfaction increased by 0.08 in the least financially worried, while it decreased by 0.06 in the most financially worried.

When we regressed life satisfaction on the three land use variables instead of NDVI, we observed neither main association nor moderations (likelihood ratio test p-values for interaction with age, household income, and financial worries were 0.62, 0.43, and 0.38, respectively; figures S3–S5 and table S2).

When we regressed life satisfaction on proximity to greenspace, the interactions with age and household income remained significant (likelihood ratio test p-values were 0.0062 and 0.0024, respectively), while the interaction with financial worries disappeared (likelihood ratio test p-value was 0.30). Increased route to forest, but not to park or to agricultural area, was associated with higher life satisfaction in the youngest age group (figure S6 and table S3a). Increased route to all three greenspaces was associat-

Figure 3: NDVI association with life satisfaction by age categories, adjusted for life satisfaction in the past, sex, household income, financial worries, canton, degree of urbanisation, and month of entry.

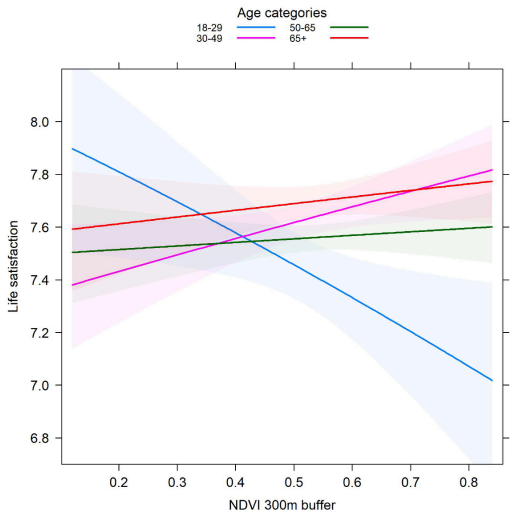


Table 2:
Moderation by age categories (likelihood ratio test p-value = 0.016). Results from Beta regression of life satisfaction on NDVI by age categories, adjusted for life satisfaction in the past, sex, household income, financial worries, canton, degree of urbanisation, and month of entry.

	Coefficient	Standard error	p-value
ndvi_buff300	–0.632	0.264	0.017
ndvi_buff300:agecat30-49	0.955	0.295	0.001
ndvi_buff300:agecat50-65	0.703	0.280	0.012
ndvi_buff300:agecat65+	0.770	0.293	0.009
agecat30-49	–0.394	0.156	0.012
agecat50-65	–0.301	0.150	0.044
agecat65+	–0.262	0.157	0.094
satisf_past_prop	3.822	0.063	0.000
sexMale	0.080	0.017	1.84E-06
hh_income6000-15000	–0.022	0.019	0.266
hh_income15000+	–0.019	0.028	0.495
finwor_3catMiddle	0.177	0.021	4.39E-17
finwor_3catLow	0.355	0.022	1.60E-59
kantonBL	–0.005	0.021	0.818
urbanity300-1500	0.019	0.025	0.440
urbanity<300	0.059	0.041	0.154
mon_entry_2catT2	–0.174	0.018	2.42E-23

satisf_now_prop ~ ndvi_buff300 * agecat + satisf_past_prop + sex + hh_income + finwor_3cat + kanton + urbanity + mon_entry_2cat

satisf_now_prop: life satisfaction scaled to (0,1)

ndvi_buff300: mean NDVI within 300 m circular buffer

agecat: age categorised into 18–29 years, 30–49 years, 50–65 years, and 65+ years

satisf_past_prop: life satisfaction in the past scaled to (0,1)

sex: female vs male

hh_income: household income categorised into <6,000, 6,000–15,000, or 15,000+ CHF/month

finwor_3cat: terciles of financial worries on a scale from 0 to 10

kanton: Basel-Stadt (BS) vs Basel-Landschaft (BL)

urbanity: degree of urbanisation categorised into <300, 300–1,500, 1,500+ inhabitants/km2

mon_entry_2cat: month of entry from July to October 2020 vs from November 2020 to March 2021

ed with lower life satisfaction in the participants with high household income, in line with the NDVI effects (figure S7 and table S3b). Increased route to forest, but not to park or to agricultural area, was associated with lower life satisfaction in the least financially worried but with wide confidence interval (figure S8 and table S3c).

Ordered probit regression resulted in similar results as Beta regression (tables S4–S7).

Discussion

In this cross-sectional study of Basel dwellers, we observed that during the COVID-19 pandemic the residential greenness affects life satisfaction differently, depending on

Figure 4: NDVI association with life satisfaction by household income, adjusted for life satisfaction in the past, age categories, sex, financial worries, canton, degree of urbanisation, and month of entry.

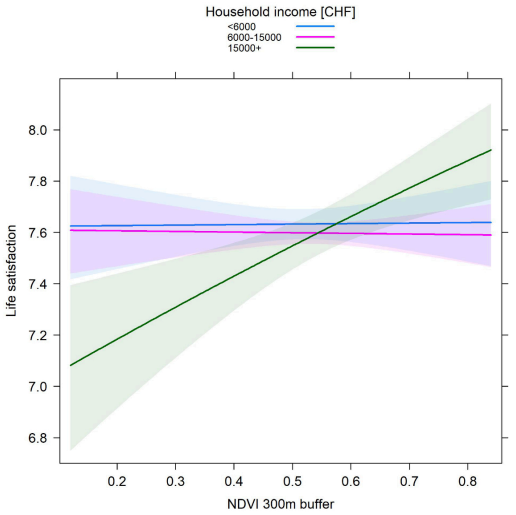


Figure 5: NDVI association with life satisfaction by financial worries, adjusted for life satisfaction in the past, age categories, sex, household income, canton, degree of urbanisation, and month of entry.

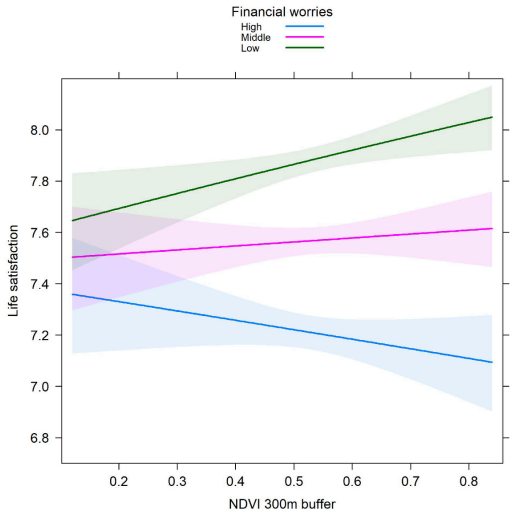


Table 3:
Moderation by household income (likelihood ratio test p-value = 0.0049). Results from Beta regression of life satisfaction on NDVI by household income, adjusted for life satisfaction in the past, age categories, sex, financial worries, canton, degree of urbanisation, and month of entry.

	Coefficient	Standard error	p-value
ndvi_buff300	0.011	0.133	0.936
ndvi_buff300:hh_income6000-15000	–0.024	0.155	0.877
ndvi_buff300:hh_income15000+	0.600	0.212	0.005
hh_income6000-15000	–0.006	0.084	0.943
hh_income15000+	–0.345	0.117	0.003
satisf_past_prop	3.825	0.063	0.000
agecat30-49	0.098	0.037	0.007
agecat50-65	0.061	0.035	0.083
agecat65+	0.138	0.036	1.59E-04
sexMale	0.079	0.017	2.27E-06
finwor_3catMiddle	0.179	0.021	2.65E-17
finwor_3catLow	0.354	0.022	2.19E-59
kantonBL	–0.003	0.021	0.877
urbanity300-1500	0.020	0.025	0.408
urbanity<300	0.067	0.041	0.108
mon_entry_2catT2	–0.175	0.018	1.56E-23

satisf_now_prop ~ ndvi_buff300 * hh_income + satisf_past_prop + agecat + sex + finwor_3cat + kanton + urbanity + mon_entry_2cat

satisf_now_prop: life satisfaction scaled to (0,1)

ndvi_buff300: mean NDVI within 300 m circular buffer

hh_income: household income categorised into <6,000, 6,000–15,000, or 15,000+ CHF/month

satisf_past_prop: life satisfaction in the past scaled to (0,1)

agecat: age categorised into 18–29 years, 30–49 years, 50–65 years, and 65+ years

sex: female vs male

finwor_3cat: terciles of financial worries on a scale from 0 to 10

kanton: Basel-Stadt (BS) vs Basel-Landschaft (BL)

urbanity: degree of urbanisation categorised into <300, 300–1,500, 1,500+ inhabitants/km2

mon_entry_2cat: month of entry from July to October 2020 vs from November 2020 to March 2021

their age, household income, and financial worries. Living in a greener area does not benefit all dwellers in Basel and its region equally, with those with high household income and not financially worried having the largest benefit. For the young adults and the financially worried, higher greenness was in fact associated with lower life satisfaction.

Multiple studies demonstrated mental health benefits of greenspace use in the COVID-19 context. In a survey in the UK, higher NDVI indicating a greener and potentially more pleasant living area was associated with better mental well-being, and increased time spent in nature was associated with less perceived stress [27]. In an online survey in South Korea, albeit not population-representative like COVCO-Basel, decreased use of greenspace during the pandemic was associated with higher risk of major depression [28]. Another online survey in Tokyo showed beneficial effects of greenspace on mental health outcomes including life satisfaction [29]. In an online survey for college students in the USA, reduced use of public parks was associated with higher emotional stress, while national/state park availability per capita was associated with lower emotional stress [30]. The South Korean study [28] examined moderation by education, urbanicity, or perceived safety level in neighbourhood with no significant finding, while the other studies [27, 29, 30] did not assess moderation.

In this current study, the life satisfaction of young adults (age group 18–29 years) was negatively associated with residential greenness. This may indicate that younger people perceive greenness or use greenspace differently than older people. Indeed, we observed that the life satisfaction of young adults was negatively associated with proximity to forest, but not to park or to agricultural area, suggesting that greenspace usage varies by age groups. Younger people may feel rather isolated in rural area, which is greener but farther away from inner city's facilities. Younger people may use greenspace more for socializing purposes, and therefore be more affected by the containment measures that prevent using the greenspace in their neighbourhood in the way they used to. Age-specific patterns of greenspace use have been observed in other studies. A nationwide study in Denmark reported that reasons to visit greenspaces differed by gender and age [31]. Stress reduction and social interaction were important reasons for younger age group to visit greenspaces but not for people over 65 years. A survey on the visitors of small public urban greenspaces [32] showed that older people visited the greenspaces for rest and restitution while younger people for socialising. In a COVID-19 survey in Belgium, younger people reported higher intention to increase greenspace visits in future compared to older people [33]. This finding warrants follow-up analyses to better understand what factors are essential to the well-being of young adults.

Socio-economic position (SEP)-dependent greenness effects were also observed for mortality in the Swiss National Cohort study conducted before the COVID-19 pandemic [25]. Given that the positive associations of proximity to greenspace with life satisfaction in the high-income group was consistent across different types of greenspace, we believe the differential usage alone cannot explain the SEP-dependent greenness effects on life satisfaction. Subjects with increased emotional or mental stress may have less re-

Table 4:
Moderation by financial worries (likelihood ratio test p-value = 0.014). Results from Beta regression of life satisfaction on NDVI by financial worries, adjusted for life satisfaction in the past, age categories, sex, household income, canton, degree of urbanisation, and month of entry.

	Coefficient	Standard error	p-value
ndvi_buff300	–0.180	0.136	0.186
ndvi_buff300:finwor_3catMiddle	0.261	0.172	0.129
ndvi_buff300:finwor_3catLow	0.502	0.170	0.003
finwor_3catMiddle	0.042	0.094	0.651
finwor_3catLow	0.089	0.093	0.336
satisf_past_prop	3.824	0.063	0.000
agecat30-49	0.096	0.037	0.009
agecat50-65	0.057	0.035	0.102
agecat65+	0.133	0.036	2.68E-04
sexMale	0.079	0.017	2.24E-06
hh_income6000-15000	–0.020	0.019	0.314
hh_income15000+	–0.018	0.028	0.524
kantonBL	–0.004	0.021	0.862
urbanity300–1500	0.018	0.025	0.467
urbanity<300	0.060	0.041	0.149
mon_entry_2catT2	–0.175	0.018	1.70E–23

satisf_now_prop ~ ndvi_buff300 * finwor_3cat + satisf_past_prop + agecat + sex + hh_income + kanton + urbanity + mon_entry_2cat

satisf_now_prop: life satisfaction scaled to (0,1)

ndvi_buff300: mean NDVI within 300 m circular buffer

finwor_3cat: terciles of financial worries on a scale from 0 to 10

satisf_past_prop: life satisfaction in the past scaled to (0,1)

agecat: age categorised into 18–29 years, 30–49 years, 50–65 years, and 65+ years

sex: female vs male

hh_income: household income categorised into <6,000, 6,000–15,000, or 15,000+ CHF/month

kanton: Basel-Stadt (BS) vs Basel-Landschaft (BL)

urbanity: degree of urbanisation categorised into <300, 300–1,500, 1,500+ inhabitants/km2

mon_entry_2cat: month of entry from July to October 2020 vs from November 2020 to March 2021

sources and/or less opportunities to access the restorative potential of greenspace compared to less stressed subjects. In a recent ecological momentary assessment of university students, stress and negative affect was bi-directionally associated with less physical activity [34]. Physical activity has been shown either to mediate [35] or to moderate [36] the greenness effects on psychological well-being. Persons with higher household income are also more likely to have jobs that allow for home office. Working at home would allow them to more actively benefit from greenspace in their neighbourhood. A recent cross-sectional study in the British adults, manual workers visited green space less than non-manual workers when the movement restriction was enforced as a COVID-19 containment measure [37].

NDVI effects cannot be attributed to any specific type of greenspace analysed in this study, i.e. forest, park, and agricultural area. Basel dwellers may benefit from other types of greenspace such as private gardens, sports fields, street trees, etc., which the land use data used in this study do not delineate. The majority of the participants in a UK survey reported increased time spent in nature as a result of COVID-19 pandemic, mainly in private gardens [27]. In a survey in Tokyo, green views from windows showed greater effects on mental health outcomes than greenspace use, suggesting that the benefits of nature exposure need not act through direct experience [29].

Strength and limitations

In this study we produced the first evidence on the association between residential greenness and life satisfaction during the COVID-19 pandemic, from a population-based sample of Swiss adults. By investigating the effect moderation for a priori selected variables, we demonstrated the differential benefits of residential greenness by sociodemographic characteristics.

This study is by design cross-sectional and does not provide causal evidence. Although we adjusted the regression models for a number of covariates, our findings may still be biased by unobserved confounders. There could be many other built environment-related characteristics that may correlate with greenness as well as associated with subjective well-being. However, as we objectively assessed the explanatory variables, our findings in this study are unlikely biased by reverse causation. Nevertheless, as our primary interest is in the effect of residential greenspace on promoting life satisfaction, we cannot exclude the alternative explanation that a high income goes along with better life satisfaction and choosing green neighbourhoods for residence. The low participation rate in the study limits the generalisability of the results and could have introduced selection bias. Bias could have resulted from restricting analysis to the study sample without missing information on the variables considered. Finally, the current study is focused on a widely used single question for life satisfaction as an endpoint. This limits its comparability with studies that use more detailed instruments.

Given the generally high level of greenspace in Swiss urban and periurban space compared to other cities in Europe or elsewhere and given the wide heterogeneity of greenspace distribution and population characteristics, our findings from Basel dwellers may not be generalised to other settings. Future research is warranted to investigate how people use and interact with the various greenspace, and if use pattern and life stress modulate the greenspace effects on well-being.

Conclusions

The effect of residential greenness on life satisfaction during the COVID-19 pandemic varies by sociodemographic characteristics. People of high SEP benefit most from living in a green environment. The association between residential greenness and life satisfaction cannot be attributed to specific types of greenspace. Deeper understanding of the mechanism behind the association between greenspace and well-being is required for urban engineering to improve the urban dwellers' well-being in different age and social strata.

Data availability

The data that support the findings of this study are available upon reasonable request from the corresponding author, Ayoung Jeong, and the principal investigator of the COVCO-Basel cohort, Nicole Probst-Hensch.

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Potential competing interests

All authors have completed and submitted the International Committee of Medical Journal Editors form for disclosure of potential conflicts of interest. No potential conflict of interest was disclosed.

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Appendix

Table S1. Results from Beta regression of life satisfaction on NDVI adjusted for life satisfaction in the past, age categories, sex, household income, financial worries, canton, degree of urbanisation, and month of entry

	Coefficient	Standard error	P-value
ndvi_buff300	0.101	0.082	0.214
satisf_past_prop	3.823	0.063	0.000
agecat30-49	0.097	0.037	0.008
agecat50-65	0.059	0.035	0.091
agecat65+	0.134	0.036	2.47E-04
sexMale	0.08	0.017	1.85E-06
hh_income6000-15000	-0.021	0.019	0.281
hh_income15000+	-0.019	0.028	0.505
finwor_3catMiddle	0.178	0.021	3.07E-17
finwor_3catLow	0.355	0.022	2.07E-59
kantonBL	-0.004	0.021	0.858
urbanity300-1500	0.017	0.025	0.487
urbanity<300	0.057	0.041	0.165
mon_entry_2catT2	-0.175	0.018	1.79E-23

satisf_now_prop ~ ndvi_buff300 + satisf_past_prop + agecat + sex + hh_income + finwor_3cat + kanton + urbanity + mon_entry_2cat

satisf_now_prop: life satisfaction scaled to (0,1)
ndvi_buff300: mean NDVI within 300 m circular buffer
satisf_past_prop: life satisfaction in the past scaled to (0,1)
agecat: age categorised into 18-29 years, 30-49 years, 50-65 years, and 65+ years
sex: female vs male
hh_income: household income categorised into <6000, 6000-15000, or 15000+ CHF/month
finwor_3cat: terciles of financial worries on a scale from 0 to 10
kanton: Basel-Stadt (BS) vs Basel-Landschaft (BL)
urbanity: degree of urbanisation categorised into <300, 300-1500, 1500+ inhabitants/km2
mon_entry_2cat: month of entry from July to October 2020 vs from November 2020 to March 2021

Table S2. Results from Beta regression of life satisfaction on land use variables (a) by age categories, (b) by household income, (c) by financial worries, adjusted for life satisfaction in the past, age categories, sex, household income, financial worries, canton, degree of urbanisation, and month of entry

(a) Moderation by age categories (likelihood ratio test p-value = 0.62)

	Coefficient	Standard error	P-value
forest_buff300	0.007	0.209	0.974
park_buff300	-0.322	0.737	0.662
agri_buff300	-0.239	0.384	0.534
forest_buff300:agecat30-49	0.197	0.233	0.399
forest_buff300:agecat50-65	0.037	0.221	0.866
forest_buff300:agecat65+	-0.031	0.227	0.890
park_buff300:agecat30-49	0.945	0.817	0.247
park_buff300:agecat50-65	0.193	0.792	0.808
park_buff300:agecat65+	0.178	0.825	0.830
agri_buff300:agecat30-49	0.430	0.429	0.316
agri_buff300:agecat50-65	0.416	0.405	0.305
agri_buff300:agecat65+	0.173	0.424	0.684
agecat30-49	0.035	0.053	0.516
agecat50-65	0.036	0.051	0.474
agecat65+	0.127	0.053	0.016
satisf_past_prop	3.828	0.063	0.000
sexMale	0.080	0.017	1.78E-06
hh_income6000-15000	-0.019	0.019	0.316
hh_income15000+	-0.019	0.028	0.510
finwor_3catMiddle	0.178	0.021	3.02E-17
finwor_3catLow	0.355	0.022	1.79E-59
kantonBL	-0.005	0.022	0.830
urbanity300-1500	0.017	0.026	0.516
urbanity<300	0.056	0.044	0.199
mon_entry_2catT2	-0.174	0.018	3.12E-23

satisf_now_prop ~ (forest_buff300 + park_buff300 + agri_buff300) * agecat + satisf_past_prop + sex + hh_income + finwor_3cat + kanton + urbanity + mon_entry_2cat

(b) Moderation by household income (likelihood ratio test p-value = 0.43)

	Coefficient	Standard error	P-value
forest_buff300	0.041	0.095	0.663
park_buff300	0.362	0.348	0.298
agri_buff300	0.014	0.191	0.941
forest_buff300:hh_income6000-15000	-0.036	0.114	0.754
forest_buff300:hh_income15000+	0.238	0.158	0.131
park_buff300:hh_income6000-15000	-0.456	0.424	0.281
park_buff300:hh_income15000+	-0.376	0.640	0.557
agri_buff300:hh_income6000-15000	0.077	0.223	0.728
agri_buff300:hh_income15000+	0.193	0.298	0.518
hh_income6000-15000	-0.004	0.028	0.884
hh_income15000+	-0.035	0.041	0.390
satisf_past_prop	3.828	0.063	0.000
agecat30-49	0.096	0.037	0.009
agecat50-65	0.060	0.035	0.087
agecat65+	0.135	0.036	2.07E-04
sexMale	0.079	0.017	2.43E-06
finwor_3catMiddle	0.179	0.021	2.10E-17
finwor_3catLow	0.355	0.022	1.60E-59
kantonBL	-0.005	0.022	0.816
urbanity300-1500	0.019	0.026	0.461
urbanity<300	0.064	0.044	0.146
mon_entry_2catT2	-0.176	0.018	1.17E-23

satisf_now_prop ~ (forest_buff300 + park_buff300 + agri_buff300) * hh_income + satisf_past_prop + agecat + sex + finwor_3cat + kanton + urbanity + mon_entry_2cat

(c) Moderation by financial worries (likelihood ratio test p-value = 0.38)

	Coefficient	Standard error	P-value
forest_buff300	-0.115	0.097	0.238
park_buff300	-0.150	0.355	0.672
agri_buff300	0.231	0.203	0.254
forest_buff300:finwor_3catMiddle	0.261	0.128	0.041
forest_buff300:finwor_3catLow	0.217	0.125	0.081
park_buff300:finwor_3catMiddle	0.457	0.469	0.330
park_buff300:finwor_3catLow	0.129	0.477	0.788
agri_buff300:finwor_3catMiddle	-0.238	0.245	0.332
agri_buff300:finwor_3catLow	-0.097	0.252	0.699
finwor_3catMiddle	0.151	0.031	1.05E-06
finwor_3catLow	0.335	0.031	1.49E-26
satisf_past_prop	3.825	0.063	0.000
agecat30-49	0.095	0.037	0.009
agecat50-65	0.059	0.035	0.090
agecat65+	0.134	0.036	2.27E-04
sexMale	0.080	0.017	2.00E-06
hh_income6000-15000	-0.019	0.019	0.323
hh_income15000+	-0.016	0.028	0.572
kantonBL	-0.004	0.022	0.844
urbanity300-1500	0.017	0.026	0.507
urbanity<300	0.057	0.044	0.192
mon_entry_2catT2	-0.175	0.018	1.80E-23

satisf_now_prop ~ (forest_buff300 + park_buff300 + agri_buff300) * finwor_3cat + satisf_past_prop + agecat + sex + hh_income + kanton + urbanity + mon_entry_2cat

satisf_now_prop: life satisfaction scaled to (0,1)
forest_buff300: proportion of area covered by forest within 300 m circular buffer
park_buff300: proportion of area covered by urban parks within 300 m circular buffer
agri_buff300: proportion of area covered by agricultural area within 300 m circular buffer
agecat: age categorised into 18-29 years, 30-49 years, 50-65 years, and 65+ years
hh_income: household income categorised into <6000, 6000-15000, or 15000+ CHF/month
finwor_3cat: terciles of financial worries on a scale from 0 to 10
satisf_past_prop: life satisfaction in the past scaled to (0,1)
sex: female vs male
kanton: Basel-Stadt (BS) vs Basel-Landschaft (BL)
urbanity: degree of urbanisation categorised into <300, 300-1500, 1500+ inhabitants/km2
mon_entry_2cat: month of entry from July to October 2020 vs from November 2020 to March 2021

Table S3. Results from Beta regression of life satisfaction on proximity to greenspace (a) by age categories, (b) by household income, (c) by financial worries, adjusted for life satisfaction in the past, age categories, sex, household income, financial worries, canton, degree of urbanisation, month of entry, and NDVI

(a) Moderation by age categories (likelihood ratio test p-value = 0.0062)

	Coefficient	Standard error	P-value
forest_route	0.109	0.048	0.022
park_route	-0.006	0.007	0.370
agri_route	-0.010	0.028	0.710
forest_route:agecat30-49	-0.073	0.054	0.177
forest_route:agecat50-65	-0.105	0.051	0.039
forest_route:agecat65+	-0.157	0.054	0.004
park_route:agecat30-49	0.010	0.008	0.203
park_route:agecat50-65	0.003	0.007	0.652
park_route:agecat65+	0.006	0.008	0.440
agri_route:agecat30-49	-0.019	0.031	0.547
agri_route:agecat50-65	-0.012	0.029	0.687
agr_route:agecat65+	0.035	0.031	0.256
agecat30-49	0.171	0.074	0.021
agecat50-65	0.169	0.070	0.017
agecat65+	0.210	0.074	0.005
ndvi_buff300	0.091	0.084	0.276
satisf_past_prop	3.821	0.063	0.000
sexMale	0.081	0.017	1.62E-06
hh_income6000-15000	-0.021	0.019	0.288
hh_income15000+	-0.017	0.028	0.550
finwor_3catMiddle	0.180	0.021	1.58E-17
finwor_3catLow	0.358	0.022	2.23E-60
kantonBL	-0.015	0.025	0.560
urbanity300-1500	0.020	0.027	0.461
urbanity<300	0.063	0.047	0.178
mon_entry_2catT2	-0.177	0.018	5.58E-24

satisf_now_prop ~ (forest_route + park_route + agri_route) * agecat + ndvi_buff300 + satisf_past_prop + sex + hh_income + finwor_3cat + kanton + urbanity + mon_entry_2cat

(b) Moderation by household income (likelihood ratio test p-value = 0.0024)

	Coefficient	Standard error	P-value
forest_route	0.043	0.022	0.055
park_route	-0.004	0.003	0.201
agri_route	-0.028	0.013	0.031
forest_route:hh_income6000-15000	-0.040	0.028	0.152
forest_route:hh_income15000+	-0.124	0.042	0.003
park_route:hh_income6000-15000	0.007	0.004	0.067
park_route:hh_income15000+	-0.008	0.007	0.213
agri_route:hh_income6000-15000	0.033	0.015	0.031
agri_route:hh_income15000+	-0.007	0.021	0.719
hh_income6000-15000	-0.055	0.037	0.137
hh_income15000+	0.113	0.055	0.040
ndvi_buff300	0.103	0.084	0.218
satisf_past_prop	3.834	0.063	0.000
agecat30-49	0.099	0.037	0.007
agecat50-65	0.062	0.035	0.076
agecat65+	0.138	0.036	1.58E-04
sexMale	0.079	0.017	2.33E-06
finwor_3catMiddle	0.178	0.021	3.85E-17
finwor_3catLow	0.353	0.022	6.40E-59
kantonBL	-0.016	0.025	0.523
urbanity300-1500	0.025	0.027	0.357
urbanity<300	0.067	0.047	0.153
mon_entry_2catT2	-0.176	0.018	8.28E-24

satisf_now_prop ~ (forest_route + park_route + agri_route) * hh_income + ndvi_buff300 + satisf_past_prop + agecat + sex + finwor_3cat + kanton + urbanity + mon_entry_2cat

(c) Moderation by financial worries (likelihood ratio test p-value = 0.30)

	Coefficient	Standard error	P-value
forest_route	0.032	0.025	0.203
park_route	-0.004	0.004	0.322
agri_route	-0.015	0.013	0.253
forest_route:finwor_3catMiddle	-0.013	0.032	0.678
forest_route:finwor_3catLow	-0.058	0.033	0.082
park_route:finwor_3catMiddle	0.000	0.005	0.925
park_route:finwor_3catLow	0.007	0.005	0.119
agri_route:finwor_3catMiddle	-0.005	0.017	0.772
agri_route:finwor_3catLow	0.019	0.017	0.271
finwor_3catMiddle	0.197	0.042	2.75E-06
finwor_3catLow	0.358	0.044	4.64E-16
ndvi_buff300	0.114	0.084	0.173
satisf_past_prop	3.824	0.063	0.000
agecat30-49	0.098	0.037	0.007
agecat50-65	0.060	0.035	0.086
agecat65+	0.136	0.037	2.05E-04
sexMale	0.080	0.017	1.84E-06
hh_income6000-15000	-0.021	0.019	0.270
hh_income15000+	-0.019	0.028	0.497
kantonBL	-0.015	0.025	0.558
urbanity300-1500	0.020	0.027	0.450
urbanity<300	0.062	0.047	0.183
mon_entry_2catT2	-0.176	0.018	1.27E-23

satisf_now_prop ~ (forest_route + park_route + agri_route) * finwor_3cat + ndvi_buff300 + satisf_past_prop + agecat + sex + hh_income + kanton + urbanity + mon_entry_2cat

satisf_now_prop: life satisfaction scaled to (0,1)
forest_route: shortest route to forest in km
park_route: shortest route to urban parks in km
agri_route: shortest route to agricultural field
agecat: age categorised into 18-29 years, 30-49 years, 50-65 years, and 65+ years
hh_income: household income categorised into <6000, 6000-15000, or 15000+ CHF/month
finwor_3cat: terciles of financial worries on a scale from 0 to 10
ndvi_buff300: mean NDVI within 300 m circular buffer
satisf_past_prop: life satisfaction in the past scaled to (0,1)
sex: female vs male
kanton: Basel-Stadt (BS) vs Basel-Landschaft (BL)
urbanity: degree of urbanisation categorised into <300, 300-1500, 1500+ inhabitants/km2
mon_entry_2cat: month of entry from July to October 2020 vs from November 2020 to March 2021

Table S4. Results from ordered probit regression of life satisfaction on NDVI adjusted for life satisfaction in the past, age categories, sex, household income, financial worries, canton, degree of urbanisation, and month of entry

	Coefficient	Standard error	P-value
ndvi_buff300	0.155	0.107	0.148
satisf_past_fac1	-0.063	0.444	0.887
satisf_past_fac2	-0.347	0.390	0.374
satisf_past_fac3	0.227	0.360	0.528
satisf_past_fac4	0.480	0.349	0.168
satisf_past_fac5	0.716	0.342	0.036
satisf_past_fac6	1.092	0.339	0.001
satisf_past_fac7	1.376	0.336	4.21E-05
satisf_past_fac8	1.807	0.335	7.03E-08
satisf_past_fac9	2.358	0.335	2.01E-12
satisf_past_fac10	3.275	0.336	1.79E-22
agecat30-49	0.151	0.049	0.002
agecat50-65	0.092	0.047	0.050
agecat65+	0.161	0.049	0.001
sexMale	0.151	0.022	7.89E-12
hh_income6000-15000	0.004	0.026	0.884
hh_income15000+	0.018	0.037	0.634
finwor_3catMiddle	0.296	0.028	1.82E-25
finwor_3catLow	0.460	0.029	3.88E-56
kantonBL	-0.002	0.027	0.929
urbanity300-1500	0.030	0.032	0.357
urbanity<300	0.109	0.054	0.044
mon_entry_2catT2	-0.319	0.023	2.49E-43

satisf_now_fac ~ ndvi_buff300 + satisf_past_fac + agecat + sex + hh_income + finwor_3cat + kanton + urbanity + mon_entry_2cat

satisf_now_fac: life satisfaction as an ordinal variable
ndvi_buff300: mean NDVI within 300 m circular buffer
satisf_past_fac: life satisfaction in the past as an ordinal variable
agecat: age categorised into 18-29 years, 30-49 years, 50-65 years, and 65+ years
sex: female vs male
hh_income: household income categorised into <6000, 6000-15000, or 15000+ CHF/month
finwor_3cat: terciles of financial worries on a scale from 0 to 10
kanton: Basel-Stadt (BS) vs Basel-Landschaft (BL)
urbanity: degree of urbanisation categorised into <300, 300-1500, 1500+ inhabitants/km2
mon_entry_2cat: month of entry from July to October 2020 vs from November 2020 to March 2021

Table S5. Results from ordered probit regression of life satisfaction on NDVI (a) by age categories, (b) by household income, (c) by financial worries, adjusted for life satisfaction in the past, age categories, sex, household income, financial worries, canton, degree of urbanisation, and month of entry

(a) Moderation by age categories

	Coefficient	Standard error	P-value
ndvi_buff300	-0.691	0.356	0.052
ndvi_buff300:agecat30-49	1.128	0.396	0.004
ndvi_buff300:agecat50-65	0.791	0.377	0.036
ndvi_buff300:agecat65+	0.890	0.391	0.023
agecat30-49	-0.429	0.209	0.040
agecat50-65	-0.313	0.201	0.118
agecat65+	-0.298	0.209	0.154
satisf_past_fac1	-0.074	0.444	0.867
satisf_past_fac2	-0.337	0.391	0.389
satisf_past_fac3	0.228	0.360	0.527
satisf_past_fac4	0.472	0.349	0.175
satisf_past_fac5	0.716	0.342	0.036
satisf_past_fac6	1.094	0.339	0.001
satisf_past_fac7	1.379	0.336	4.07E-05
satisf_past_fac8	1.810	0.335	6.64E-08
satisf_past_fac9	2.360	0.335	1.91E-12
satisf_past_fac10	3.277	0.336	1.68E-22
sexMale	0.151	0.022	7.74E-12
hh_income6000-15000	0.003	0.026	0.899
hh_income15000+	0.017	0.037	0.641
finwor_3catMiddle	0.295	0.028	2.72E-25
finwor_3catLow	0.461	0.029	2.92E-56
kantonBL	-0.004	0.027	0.887
urbanity300-1500	0.032	0.032	0.322
urbanity<300	0.112	0.054	0.040
mon_entry_2catT2	-0.319	0.023	2.38E-43

satisf_now_fac ~ ndvi_buff300 * agecat + satisf_past_fac + sex + hh_income + finwor_3cat + kanton + urbanity + mon_entry_2cat

(b) Moderation by household income

	Coefficient	Standard error	P-value
ndvi_buff300	0.058	0.176	0.741
ndvi_buff300:hh_income6000-15000	-0.043	0.205	0.834
ndvi_buff300:hh_income15000+	0.677	0.279	0.015
hh_income6000-15000	0.029	0.111	0.794
hh_income15000+	-0.350	0.154	0.023
satisf_past_fac1	-0.064	0.444	0.886
satisf_past_fac2	-0.349	0.390	0.372
satisf_past_fac3	0.226	0.360	0.531
satisf_past_fac4	0.475	0.349	0.173
satisf_past_fac5	0.713	0.342	0.037
satisf_past_fac6	1.090	0.339	0.001
satisf_past_fac7	1.374	0.336	4.34E-05
satisf_past_fac8	1.806	0.335	7.07E-08
satisf_past_fac9	2.358	0.335	2.01E-12
satisf_past_fac10	3.275	0.336	1.78E-22
agecat30-49	0.153	0.049	0.002
agecat50-65	0.093	0.047	0.047
agecat65+	0.165	0.049	0.001
sexMale	0.150	0.022	1.08E-11
finwor_3catMiddle	0.297	0.028	1.27E-25
finwor_3catLow	0.460	0.029	3.72E-56
kantonBL	-0.002	0.027	0.944
urbanity300-1500	0.033	0.032	0.302
urbanity<300	0.119	0.054	0.028
mon_entry_2catT2	-0.319	0.023	2.59E-43

satisf_now_fac ~ ndvi_buff300 * hh_income + satisf_past_fac + agecat + sex + finwor_3cat + kanton + urbanity + mon_entry_2cat

(c) Moderation by financial worries

	Coefficient	Standard error	P-value
ndvi_buff300	-0.216	0.183	0.238
ndvi_buff300:finwor_3catMiddle	0.331	0.231	0.152
ndvi_buff300:finwor_3catLow	0.660	0.226	0.003
finwor_3catMiddle	0.124	0.126	0.325
finwor_3catLow	0.110	0.123	0.372
satisf_past_fac1	-0.070	0.444	0.875
satisf_past_fac2	-0.351	0.391	0.369
satisf_past_fac3	0.224	0.360	0.534
satisf_past_fac4	0.478	0.349	0.170
satisf_past_fac5	0.716	0.342	0.036
satisf_past_fac6	1.093	0.339	0.001
satisf_past_fac7	1.377	0.336	4.20E-05
satisf_past_fac8	1.809	0.335	6.81E-08
satisf_past_fac9	2.360	0.335	1.94E-12
satisf_past_fac10	3.277	0.336	1.72E-22
agecat30-49	0.150	0.049	0.002
agecat50-65	0.090	0.047	0.056
agecat65+	0.160	0.049	0.001
sexMale	0.149	0.022	1.28E-11
hh_income6000-15000	0.006	0.026	0.805
hh_income15000+	0.020	0.037	0.591
kantonBL	-0.003	0.027	0.918
urbanity300-1500	0.031	0.032	0.330
urbanity<300	0.113	0.054	0.037
mon_entry_2catT2	-0.319	0.023	2.49E-43

satisf_now_fac ~ ndvi_buff300 * finwor_3cat + satisf_past_fac + agecat + sex + hh_income + kanton + urbanity + mon_entry_2cat

satisf_now_fac: life satisfaction as an ordinal variable
ndvi_buff300: mean NDVI within 300 m circular buffer
agecat: age categorised into 18-29 years, 30-49 years, 50-65 years, and 65+ years
hh_income: household income categorised into <6000, 6000-15000, or 15000+ CHF/month
finwor_3cat: terciles of financial worries on a scale from 0 to 10
satisf_past_fac: life satisfaction in the past as an ordinal variable
sex: female vs male
kanton: Basel-Stadt (BS) vs Basel-Landschaft (BL)
urbanity: degree of urbanisation categorised into <300, 300-1500, 1500+ inhabitants/km2
mon_entry_2cat: month of entry from July to October 2020 vs from November 2020 to March 2021

Table S6. Results from ordered probit regression of life satisfaction on land use variables (a) by age categories, (b) by household income, (c) by financial worries, adjusted for life satisfaction in the past, age categories, sex, household income, financial worries, canton, degree of urbanisation, and month of entry

(a) Moderation by age categories

	Coefficient	Standard error	P-value
forest_buff300	0.006	0.284	0.984
park_buff300	0.127	0.995	0.899
agri_buff300	-0.295	0.516	0.568
forest_buff300:agecat30-49	0.204	0.315	0.517
forest_buff300:agecat50-65	0.111	0.300	0.710
forest_buff300:agecat65+	0.002	0.306	0.995
park_buff300:agecat30-49	0.629	1.099	0.567
park_buff300:agecat50-65	-0.679	1.067	0.525
park_buff300:agecat65+	-0.148	1.103	0.893
agri_buff300:agecat30-49	0.563	0.574	0.327
agri_buff300:agecat50-65	0.428	0.543	0.430
agri_buff300:agecat65+	0.210	0.565	0.709
agecat30-49	0.093	0.071	0.192
agecat50-65	0.089	0.068	0.191
agecat65+	0.161	0.071	0.022
satisf_past_fac1	-0.075	0.444	0.866
satisf_past_fac2	-0.361	0.390	0.355
satisf_past_fac3	0.209	0.360	0.562
satisf_past_fac4	0.460	0.349	0.187
satisf_past_fac5	0.698	0.342	0.041
satisf_past_fac6	1.075	0.338	0.001
satisf_past_fac7	1.361	0.336	5.09E-05
satisf_past_fac8	1.792	0.335	8.86E-08
satisf_past_fac9	2.344	0.335	2.71E-12
satisf_past_fac10	3.262	0.336	2.56E-22
sexMale	0.151	0.022	6.61E-12
hh_income6000-15000	0.006	0.026	0.815
hh_income15000+	0.018	0.037	0.624
finwor_3catMiddle	0.296	0.028	1.84E-25
finwor_3catLow	0.460	0.029	4.22E-56
kantonBL	-0.007	0.029	0.809
urbanity300-1500	0.031	0.033	0.355
urbanity<300	0.115	0.057	0.045

mon_entry_2catT2	-0.319	0.023	3.26E-43

satisf_now_fac ~ (forest_buff300 + park_buff300 + agri_buff300) * agecat + satisf_past_fac + sex + hh_income + finwor_3cat + kanton + urbanity + mon_entry_2cat

(b) Moderation by household income

	Coefficient	Standard error	P-value
forest_buff300	0.128	0.124	0.300
park_buff300	0.466	0.460	0.311
agri_buff300	-0.072	0.249	0.772
forest_buff300:hh_income6000-15000	-0.101	0.149	0.496
forest_buff300:hh_income15000+	0.191	0.205	0.350
park_buff300:hh_income6000-15000	-0.688	0.559	0.219
park_buff300:hh_income15000+	-0.690	0.843	0.413
agri_buff300:hh_income6000-15000	0.184	0.291	0.527
agri_buff300:hh_income15000+	0.280	0.387	0.469
hh_income6000-15000	0.031	0.037	0.405
hh_income15000+	0.013	0.054	0.810
satisf_past_fac1	-0.073	0.444	0.870
satisf_past_fac2	-0.361	0.391	0.355
satisf_past_fac3	0.223	0.360	0.535
satisf_past_fac4	0.471	0.349	0.176
satisf_past_fac5	0.706	0.342	0.039
satisf_past_fac6	1.081	0.339	0.001
satisf_past_fac7	1.369	0.336	4.65E-05
satisf_past_fac8	1.801	0.335	7.76E-08
satisf_past_fac9	2.352	0.335	2.33E-12
satisf_past_fac10	3.270	0.336	2.10E-22
agecat30-49	0.150	0.049	0.002
agecat50-65	0.092	0.047	0.049
agecat65+	0.162	0.049	0.001
sexMale	0.149	0.022	1.35E-11
finwor_3catMiddle	0.297	0.028	1.11E-25
finwor_3catLow	0.460	0.029	3.23E-56
kantonBL	-0.007	0.029	0.811
urbanity300-1500	0.032	0.033	0.332
urbanity<300	0.124	0.058	0.031
mon_entry_2catT2	-0.320	0.023	1.39E-43

satisf_now_fac ~ (forest_buff300 + park_buff300 + agri_buff300) * hh_income + satisf_past_fac + agecat + sex + finwor_3cat + kanton + urbanity + mon_entry_2cat

(c) Moderation by financial worries

	Coefficient	Standard error	P-value
forest_buff300	-0.085	0.131	0.520
park_buff300	-0.172	0.482	0.721
agri_buff300	0.057	0.271	0.833
forest_buff300:finwor_3catMiddle	0.222	0.170	0.191
forest_buff300:finwor_3catLow	0.275	0.165	0.095
park_buff300:finwor_3catMiddle	0.213	0.628	0.735
park_buff300:finwor_3catLow	0.247	0.632	0.696
agri_buff300:finwor_3catMiddle	-0.028	0.325	0.932
agri_buff300:finwor_3catLow	0.108	0.331	0.744
finwor_3catMiddle	0.272	0.041	4.75E-11
finwor_3catLow	0.424	0.042	2.80E-24
satisf_past_fac1	-0.067	0.444	0.880
satisf_past_fac2	-0.351	0.391	0.369
satisf_past_fac3	0.229	0.360	0.525
satisf_past_fac4	0.477	0.349	0.172
satisf_past_fac5	0.716	0.342	0.036
satisf_past_fac6	1.091	0.339	0.001
satisf_past_fac7	1.376	0.336	4.23E-05
satisf_past_fac8	1.809	0.335	6.89E-08
satisf_past_fac9	2.360	0.335	1.98E-12
satisf_past_fac10	3.278	0.336	1.71E-22
agecat30-49	0.149	0.049	0.002
agecat50-65	0.092	0.047	0.050
agecat65+	0.161	0.049	0.001
sexMale	0.150	0.022	1.09E-11
hh_income6000-15000	0.007	0.026	0.787
hh_income15000+	0.021	0.037	0.567
kantonBL	-0.006	0.029	0.836
urbanity300-1500	0.031	0.033	0.348
urbanity<300	0.119	0.057	0.038
mon_entry_2catT2	-0.320	0.023	1.70E-43

satisf_now_fac ~ (forest_buff300 + park_buff300 + agri_buff300) * finwor_3cat + satisf_past_fac + agecat + sex + hh_income + kanton + urbanity + mon_entry_2cat

satisf_now_fac: life satisfaction as an ordinal variable
forest_buff300: proportion of area covered by forest within 300 m circular buffer
park_buff300: proportion of area covered by urban parks within 300 m circular buffer
agri_buff300: proportion of area covered by agricultural area within 300 m circular buffer
agecat: age categorised into 18-29 years, 30-49 years, 50-65 years, and 65+ years
hh_income: household income categorised into <6000, 6000-15000, or 15000+ CHF/month

finwor_3cat: terciles of financial worries on a scale from 0 to 10
satisf_past_fac: life satisfaction in the past as an ordinal variable
sex: female vs male
kanton: Basel-Stadt (BS) vs Basel-Landschaft (BL)
urbanity: degree of urbanisation categorised into <300, 300-1500, 1500+ inhabitants/km2
mon_entry_2cat: month of entry from July to October 2020 vs from November 2020 to March 2021

Table S7. Results from ordered probit regression of life satisfaction on proximity to greenspace (a) by age categories, (b) by household income, (c) by financial worries, adjusted for life satisfaction in the past, age categories, sex, household income, financial worries, canton, degree of urbanisation, month of entry, and NDVI

(a) Moderation by age categories

	Coefficient	Standard error	P-value
forest_route	0.107	0.064	0.092
park_ route	-0.006	0.009	0.504
agri_ route	0.003	0.038	0.931
forest_route:agecat30-49	-0.098	0.072	0.176
forest_route:agecat50-65	-0.108	0.068	0.112
forest_route:agecat65+	-0.157	0.072	0.030
park_route:agecat30-49	0.011	0.010	0.301
park_route:agecat50-65	0.004	0.010	0.707
park_route:agecat65+	0.007	0.010	0.464
agri_route:agecat30-49	-0.026	0.042	0.541
agri_route:agecat50-65	-0.023	0.040	0.556
agr_route:agecat65+	0.036	0.041	0.386
agecat30-49	0.256	0.099	0.010
agecat50-65	0.220	0.094	0.020
agecat65+	0.232	0.099	0.019
ndvi_buff300	0.130	0.110	0.238
satisf_past_fac1	-0.062	0.445	0.889
satisf_past_fac2	-0.344	0.391	0.379
satisf_past_fac3	0.235	0.360	0.514
satisf_past_fac4	0.479	0.349	0.169
satisf_past_fac5	0.714	0.342	0.037
satisf_past_fac6	1.097	0.339	0.001
satisf_past_fac7	1.380	0.336	4.04E-05
satisf_past_fac8	1.812	0.335	6.61E-08
satisf_past_fac9	2.362	0.335	1.93E-12
satisf_past_fac10	3.279	0.336	1.69E-22
sexMale	0.151	0.022	7.39E-12
hh_income6000-15000	0.004	0.026	0.870
hh_income15000+	0.020	0.037	0.600
finwor_3catMiddle	0.298	0.028	1.13E-25
finwor_3catLow	0.463	0.029	8.36E-57
kantonBL	-0.007	0.033	0.828
urbanity300-1500	0.030	0.035	0.389

urbanity<300	0.113	0.061	0.065
mon_entry_2catT2	-0.320	0.023	1.46E-43

satisf_now_fac ~ (forest_route + park_route + agri_route) * agecat + ndvi_buff300 + satisf_past_fac + sex + hh_income + finwor_3cat + kanton + urbanity + mon_entry_2cat

(b) Moderation by household income

	Coefficient	Standard error	P-value
forest_route	0.042	0.030	0.159
park_route	-0.004	0.005	0.404
agri_route	-0.022	0.017	0.195
forest_route:hh_income6000-15000	-0.050	0.037	0.173
forest_route:hh_income15000+	-0.157	0.055	0.004
park_route:hh_income6000-15000	0.008	0.005	0.130
park_route:hh_income15000+	-0.012	0.009	0.180
agri_route:hh_income6000-15000	0.036	0.020	0.080
agri_route:hh_income15000+	-0.010	0.027	0.721
hh_income6000-15000	-0.027	0.049	0.586
hh_income15000+	0.189	0.072	0.009
ndvi_buff300	0.137	0.110	0.214
satisf_past_fac1	-0.055	0.444	0.901
satisf_past_fac2	-0.348	0.390	0.373
satisf_past_fac3	0.228	0.360	0.527
satisf_past_fac4	0.481	0.349	0.167
satisf_past_fac5	0.720	0.342	0.035
satisf_past_fac6	1.101	0.338	0.001
satisf_past_fac7	1.385	0.336	3.73E-05
satisf_past_fac8	1.817	0.335	5.88E-08
satisf_past_fac9	2.371	0.335	1.51E-12
satisf_past_fac10	3.288	0.336	1.20E-22
agecat30-49	0.154	0.049	0.002
agecat50-65	0.095	0.047	0.042
agecat65+	0.166	0.049	0.001
sexMale	0.150	0.022	1.04E-11
finwor_3catMiddle	0.296	0.028	2.15E-25
finwor_3catLow	0.459	0.029	7.59E-56
kantonBL	-0.010	0.033	0.758
urbanity300-1500	0.037	0.035	0.295
urbanity<300	0.118	0.061	0.052
mon_entry_2catT2	-0.320	0.023	1.39E-43

satisf_now_fac ~ (forest_route + park_route + agri_route) * hh_income + ndvi_buff300 + satisf_past_fac + agecat + sex + finwor_3cat + kanton + urbanity + mon_entry_2cat

(c) Moderation by financial worries

	Coefficient	Standard error	P-value
forest_route	0.020	0.034	0.566
park_route	0.001	0.005	0.885
agri_route	0.002	0.017	0.910
forest_route:finwor_3catMiddle	-0.001	0.042	0.987
forest_route:finwor_3catLow	-0.064	0.044	0.144
park_route:finwor_3catMiddle	-0.005	0.006	0.422
park_route:finwor_3catLow	0.002	0.006	0.717
agri_route:finwor_3catMiddle	-0.021	0.022	0.339
agri_route:finwor_3catLow	0.008	0.022	0.730
finwor_3catMiddle	0.343	0.056	1.15E-09
finwor_3catLow	0.499	0.058	1.48E-17
ndvi_buff300	0.152	0.110	0.167
satisf_past_fac1	-0.065	0.444	0.884
satisf_past_fac2	-0.349	0.391	0.371
satisf_past_fac3	0.232	0.360	0.519
satisf_past_fac4	0.482	0.349	0.167
satisf_past_fac5	0.716	0.342	0.036
satisf_past_fac6	1.091	0.339	0.001
satisf_past_fac7	1.376	0.336	4.23E-05
satisf_past_fac8	1.807	0.335	7.02E-08
satisf_past_fac9	2.359	0.335	1.98E-12
satisf_past_fac10	3.276	0.336	1.80E-22
agecat30-49	0.152	0.049	0.002
agecat50-65	0.092	0.047	0.049
agecat65+	0.162	0.049	0.001
sexMale	0.151	0.022	8.81E-12
hh_income6000-15000	0.003	0.026	0.896
hh_income15000+	0.018	0.037	0.638
kantonBL	-0.009	0.033	0.784
urbanity300-1500	0.031	0.035	0.375
urbanity<300	0.115	0.061	0.059
mon_entry_2catT2	-0.318	0.023	3.47E-43

satisf_now_fac ~ (forest_route + park_route + agri_route) * finwor_3cat + ndvi_buff300 + satisf_past_fac + agecat + sex + hh_income + kanton + urbanity + mon_entry_2cat

satisf_now_fac: life satisfaction as an ordinal variable
forest_route: shortest route to forest in km
park_route: shortest route to urban parks in km
agri_route: shortest route to agricultural field

agecat: age categorised into 18-29 years, 30-49 years, 50-65 years, and 65+ years
hh_income: household income categorised into <6000, 6000-15000, or 15000+ CHF/month
finwor_3cat: terciles of financial worries on a scale from 0 to 10
ndvi_buff300: mean NDVI within 300 m circular buffer
satisf_past_fac: life satisfaction in the past as an ordinal variable
sex: female vs male
kanton: Basel-Stadt (BS) vs Basel-Landschaft (BL)
urbanity: degree of urbanisation categorised into <300, 300-1500, 1500+ inhabitants/km2
mon_entry_2cat: month of entry from July to October 2020 vs from November 2020 to March 2021

Figure S1. Hypothesized pathways that potentially link green space to life satisfaction

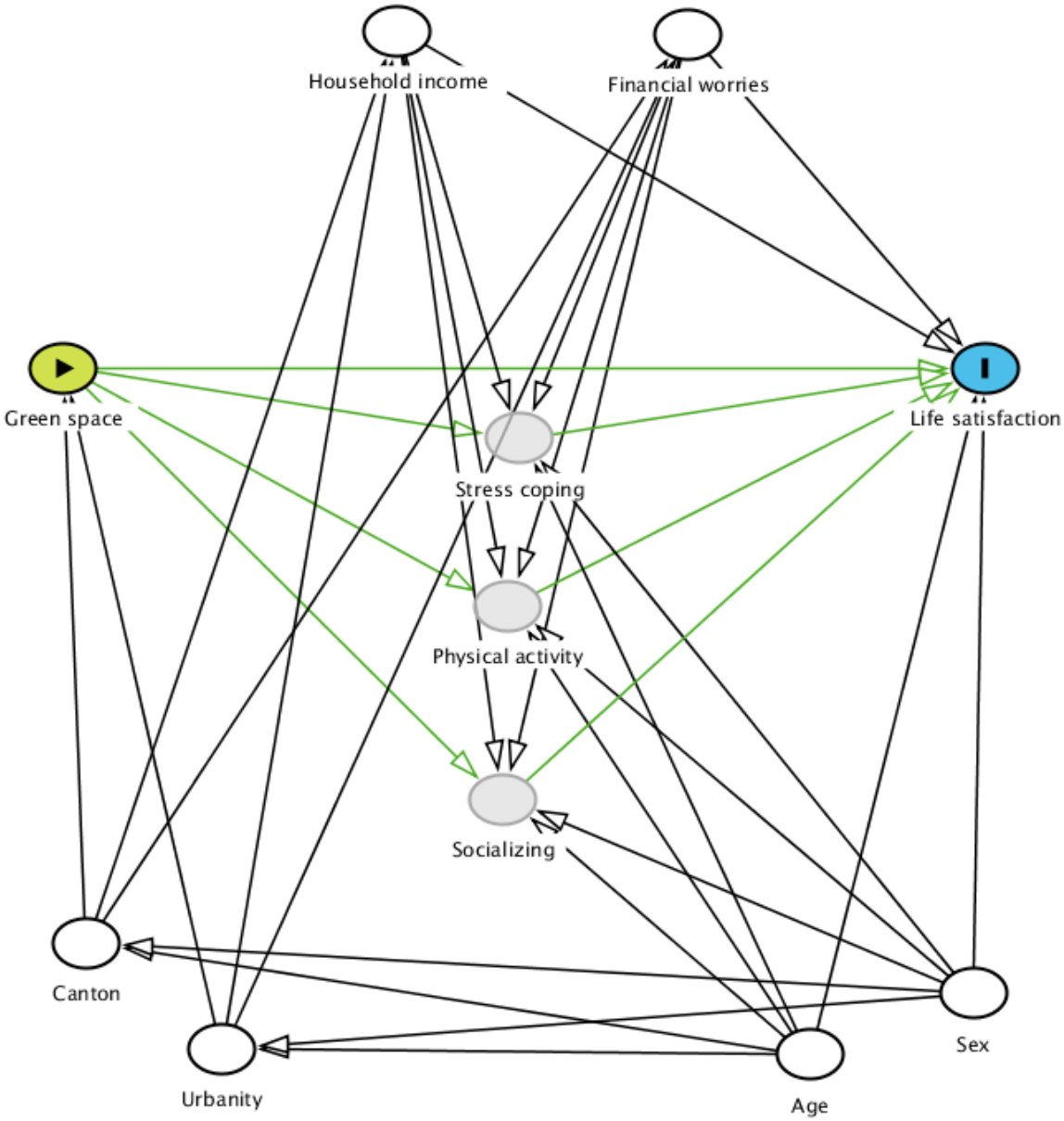

Figure S2. Pairwise correlation between greenspace variables

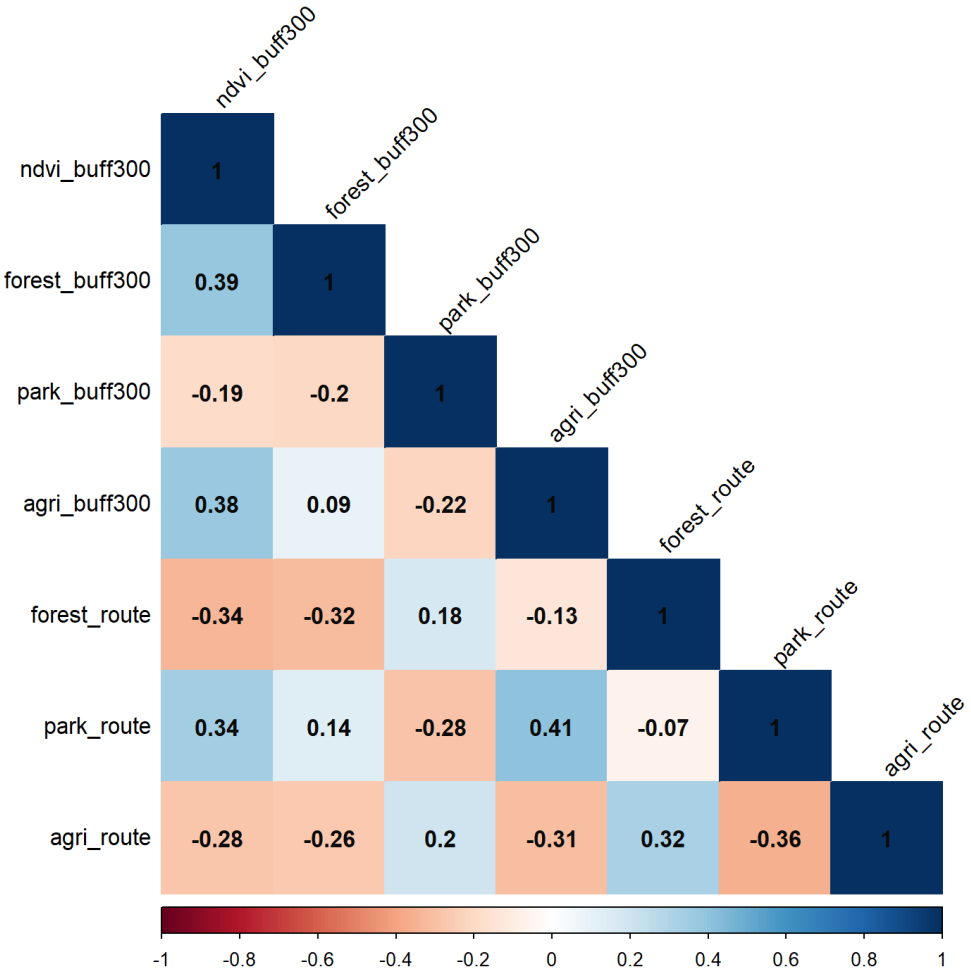

Figure S3. Mutually adjusted greenspace associations with life satisfaction by age categories, adjusted for life satisfaction in the past, sex, household income, financial worries, canton, degree of urbanisation, and month of entry

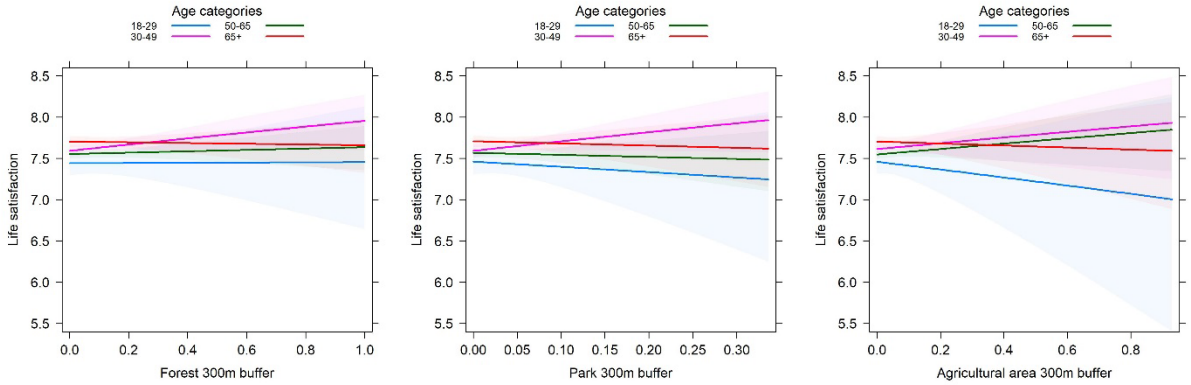

Figure S4. Mutually adjusted greenspace associations with life satisfaction by household income, adjusted for life satisfaction in the past, age categories, sex, financial worries, canton, degree of urbanisation, and month of entry

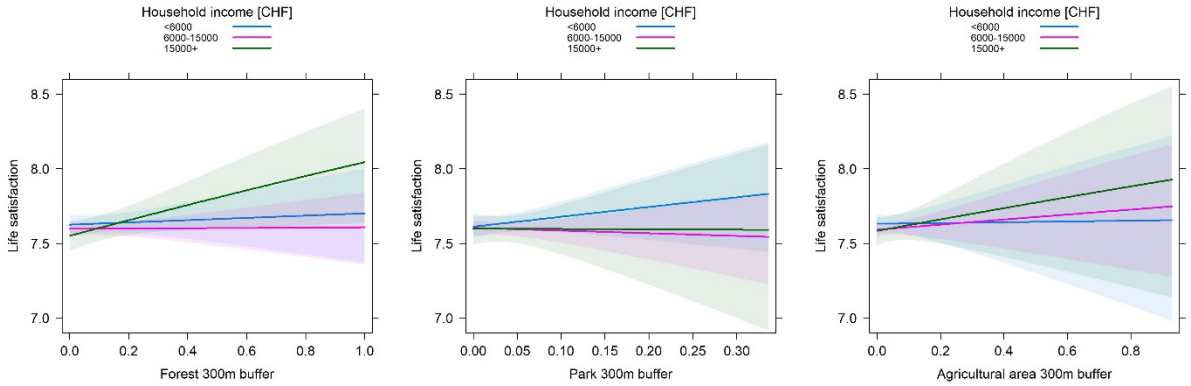

Figure S5. Mutually adjusted greenspace associations on life satisfaction by financial worries, adjusted for life satisfaction in the past, age categories, sex, household income, canton, degree of urbanisation, and month of entry

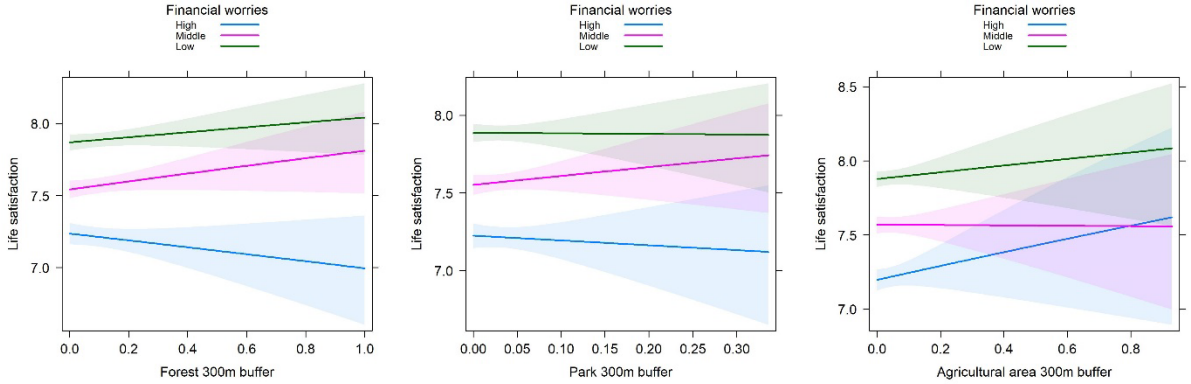

Figure S6. Mutually adjusted associations of proximity to greenspace with life satisfaction by age categories, adjusted for life satisfaction in the past, sex, household income, financial worries, canton, degree of urbanisation, month of entry, and NDVI

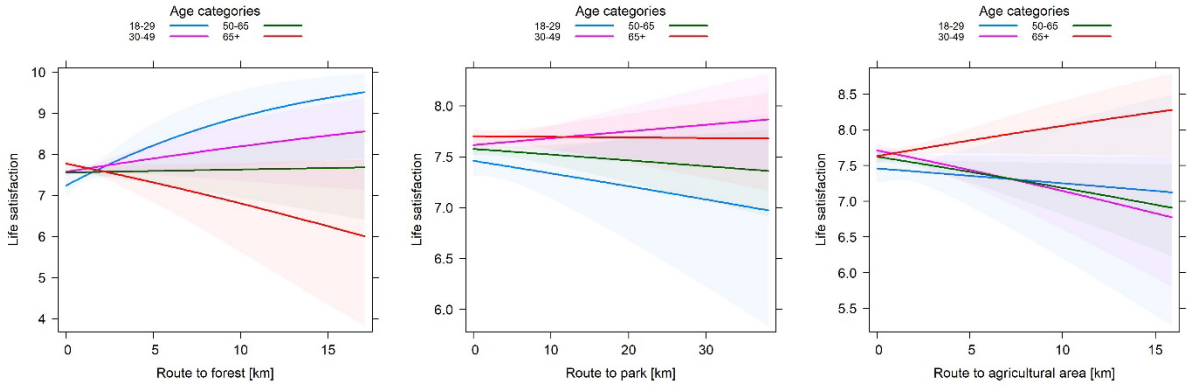

Figure S7. Mutually adjusted associations of proximity to greenspace with life satisfaction by household income, adjusted for life satisfaction in the past, age categories, sex, financial worries, canton, degree of urbanisation, month of entry, and NDVI

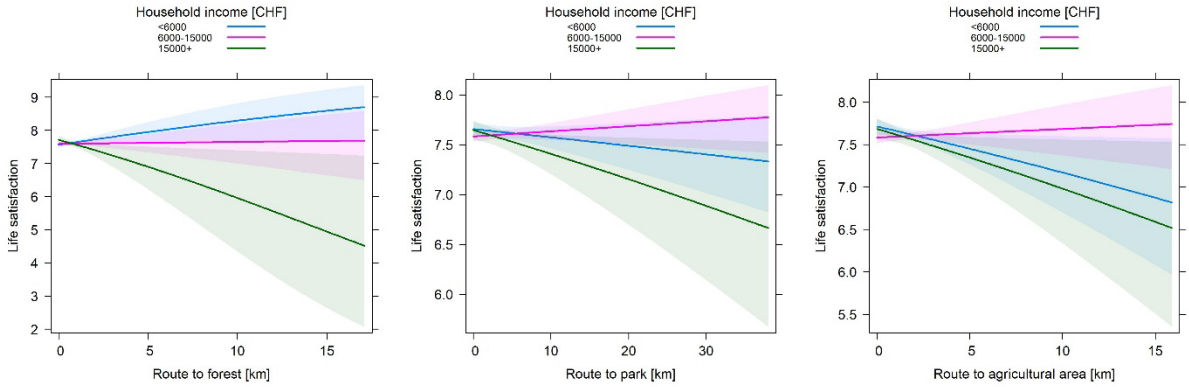

Figure S8. Mutually adjusted associations of proximity to greenspace with life satisfaction by financial worries, adjusted for life satisfaction in the past, age categories, sex, household income, canton, degree of urbanisation, month of entry, and NDVI