Kvantitativna procjena i kartiranje percepcije kulturoloških usluga i negativnosti zelene infrastrukture grada Zagreba

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QUANTITATIVE ASSESSMENT AND MAPPING OF PERCEPTION OF CULTURAL ECOSYSTEM SERVICES AND DISSERVICES OF URBAN GREEN INFRASTRUCTURE IN THE CITY OF ZAGREB

DOCTORAL THESIS

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DRVNE TEHNOLOGIJE

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DOKTORSKI RAD

Mentori:
Prof. dr. sc. Ante Seletković
Prof. dr. sc. Dagmar Haase

Zagreb, 2022.

TEMELJNA DOKUMENTACIJSKA KARTICA

TI (naslov)	Kvantitativna procjena i kartiranje percepcije kulturoloških usluga i negativnosti urbane zelene infrastrukture grada Zagreba
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PY (godina objave)	2022
LA (izvorni jezik)	Engleski
DE (ključne riječi)	PPGIS, kulturološke usluge ekosustava, negativnosti ekosustava, urbana zelena infrastruktura, grad Zagreb
GE (zemlja objave)	Republika Hrvatska
PT (vrsta objave)	Doktorska disertacija
VO (obujam)	I-XIX + 189 stranica + 15 slika + 23 tablice + 153 navoda literature
AB (sažetak)	Koncept usluga ekosustava obuhvaća sve blagodati koje različiti ekosustavi pružaju ljudima, a dijele se na usluge opskrbe, usluge podržavanja, usluge regulacije i kulturološke usluge ekosustava. U današnje vrijeme kada većina svjetske populacije živi u urbanim sredinama kulturološke usluge postaju sve važnije. One su definirane kao nematerijalne koristi koje ljudi dobivaju od ekosustava a uključuju estetiku, rekreaciju i ekoturizam, kulturne vrijednosti, sustav znanja, društvene odnose te privrženost mjestu. Iako važne, zbog svoje subjektivnosti kulturološke su usluge slabije istražene od ostalih usluga ekosustava, a njihova percepcija ovisi o karakteristikama ekosustava kao i karakteristikama korisnika tih prostora. Percipirane negativnosti definiraju se kao funkcioniranje ekosustava koje je štetno za ljudsku dobrobit. U gradovima, najvažniji izvor kulturoloških usluga ekosustava i negativnosti je urbana zelena infrastruktura. Heterogenost stanovništva, kao i heterogenost tipova urbane zelene infrastrukture njihovu procjenu i kvantifikaciju čine zahtjevnom dok podaci o proviziji i percepciji kategorija kulturoloških usluga i negativnostima u različitim tipovima zelene infrastrukture nedostaju. Informacija o načinu na koji korisnici percipiraju i koriste različite tipove urbane zelene infrastrukture može poslužiti prilikom unaprjeđenja planiranja i gospodarenja istom. Prostorno eksplicitne metode prikupljanja podataka o percepciji od samih korisnika prostora pokazale su se vrlo korisnima.

U ovom istraživanju pomoću Internetskog PPGIS (engl. *Public Participation Geographic Information System*) upitnika na uzorku punoljetnih stanovnika grada Zagreba prikupili su se prostorni podaci o percepciji pet kategorija i povezanih atributa kulturoloških usluga (privrženost mjestu, rekreacija, estetika, edukacija, kulturni identitet) te percipiranih negativnosti u urbanoj zelenoj infrastrukturi grada Zagreba. 384 sudionika u istraživanju kartiralo je 5757 prostornih markera označavajući lokacije percepcije kulturoloških usluga i negativnosti urbane zelene infrastrukture. Kategorije privrženosti mjestu, rekreacije, estetike te kulturnog identiteta kartiralo je više sudionika dok su edukacija i negativnosti kartirane od strane manjeg broja sudionika u istraživanju. Šetnja je kao atribut rekreacije, prirodnost kao atribut estetike te percepcija neodržavanih zelenih površina kao atribut negativnosti kartirani su od najvećeg broja sudionika među atributima. Parkovi, šume, park šume, ostale zelene površine, Botanički/Zoološki vrt i zelenilo oko vodenih površina najčešće su kartirani tipovi urbane zelene infrastrukture u Zagrebu, a definirano ih je ukupno 20.

Utvrđena je razlika u percepciji kulturoloških usluga i negativnosti u odnosu na tip urbane zelene infrastrukture. Vizualizacijom prostornih podataka određene su najvažnije lokacije percepcije kulturoloških usluga i negativnosti u Zagrebu. Nadalje, utvrđena je razlika u udaljenosti od doma ispitanika na kojoj se pojedina percepcija ili korištenje pojavljuje. Definiran je i opisan urbano-ruralni gradijent grada Zagreba. Sociodemografke karakteristike sudionika te njihove uobičajene navike prilikom korištenja zelenih površina nisu značajnije utjecale na izraženu percepciju kulturoloških usluga i negativnosti u urbanoj zelenoj infrastrukturi.

Ovom se disertacijom prvi put primijenio PPGIS upitnik za prikupljanje prostornih podataka od stanovnika grada Zagreba o njihovoj percepciji kulturoloških usluga i negativnosti urbane zelene infrastrukture. Definirane razlike u percepciji i načinu korištenja pojedinih tipova urbane zelene infrastrukture u Zagrebu mogu se iskoristiti za unaprjeđenje dugoročnog planiranja i gospodarenja tim prostorima u suradnji s građanima, korisnicima prostora.

BASIC DOCUMENTATION CARD

TI (Title)	Quantitative assessment and mapping of perception of cultural ecosystem services and disservices of urban green infrastructure in the city of Zagreb
OT (Original title)	Quantitative assessment and mapping of perception of cultural ecosystem services and disservices of urban green infrastructure in the city of Zagreb
AU (Author)	Martina Kičić
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SO (Source)	Library of Faculty of Forestry and Wood Technology, University of Zagreb, Svetošimunska cesta 23, 10000 Zagreb; Library of Croatian Forest Research Institute, Cvjetno naselje 41, 10450 Jastrebarsko
PY (Publication year)	2022
LA (Text language)	English
DE (Descriptors)	PPGIS, cultural ecosystem services, ecosystem disservices, urban green infrastructure, city of Zagreb
GE (Geo. Headings)	Republic of Croatia
PT (Publication Type)	Doctoral Thesis
VO (Volume)	I-XIX + 189 pages + 15 figures + 23 tables + 153 references
AB (Abstract)	Ecosystem services are all the benefits people obtain from different ecosystems and include provisioning services, supporting services, regulating services and cultural services. Today, when more than half of the world's population is living in urban areas, cultural ecosystem services are increasingly important. They are defined as non-material benefits people obtain from ecosystems and include aesthetics, recreation and ecotourism, cultural values, knowledge transfer, social relations, and place attachment. Although important, they are less explored in relation to other ecosystem services because of their subjective dimension. How they are perceived depends on the characteristics of the ecosystem as well as the characteristics of users of that place. Disservices are defined as functioning of an ecosystem that is negative for human well-being. Urban green infrastructure is the main provider of cultural ecosystem services and disservices in cities. Heterogeneity of urban population as well as heterogeneity of urban green infrastructure make the assessment and quantification of perception of cultural ecosystem services and disservices difficult. However, knowledge on how different types of urban

green infrastructure and perceived and used is still missing. The data about the ways in which users perceive and use different urban green infrastructure types can help to enhance planning and management of those spaces. In that regard, spatially explicit methods of data collection from direct users proved very beneficial.

Within this research, online PPGIS (Public Participation Geographic Information System) questionnaire was used to collect spatial data about the perception of five categories (place attachment, recreation, aesthetics, education, cultural identity) and associated attributes of cultural ecosystem services and disservices in urban green infrastructure on a sample of citizens of Zagreb. In total, 384 respondents mapped 5,757 spatial markers designating locations perceived as providers of cultural ecosystem services and disservices of urban green infrastructure. Categories of place attachment, recreation, aesthetics, and cultural identity have been mapped by more respondents than education and disservices within this research. Walking as the attribute of recreation, Naturalness as the attribute od aesthetics and Unmaintained as the attribute of disservices were mapped by the largest number of respondents among attributes for each category. Parks, forests, park forests, other green spaces, Botanical/Zoo garden and greenery around water features are the most often mapped types of urban green infrastructure among 20 defined types.

Difference in perception in relation to urban green infrastructure types has been observed. The most important locations in the city of Zagreb have been defined using visualization tools. Also, difference between distances from respondent's home to locations providing each perception or use have also been found. Urban-rural gradient has been defined and described for the city of Zagreb. Socio-demographic characteristics or visiting behaviour of respondents in the sample did not influence stated perception of cultural ecosystem services and disservices of urban green infrastructure.

Within this thesis, the first use of PPGIS questionnaire for spatial data collection about their perception of cultural ecosystem services and disservices from citizens of Zagreb was presented. Defined differences in perception and use of urban green infrastructure types in the city of Zagreb can be used to enhance long-term planning and management of those places in cooperation with citizens, the users of those places.

Ante Seletković, PhD

Ante Seletković is a full professor at the Faculty of Forestry and Wood Technology at University of Zagreb. He was born on 28th September 1975 in Zagreb. After obtaining a degree at the Faculty of Forestry, University of Zagreb he started working at the Croatian Forest Research Institute. Since 2004 he has been employed at the Faculty of Forestry and Wood Technology, University of Zagreb. He obtained his PhD (topic: Comparison between digital and visual interpretation of high-resolution satellite imagery) in 2007 at the Faculty of Forestry, University of Zagreb.

Currently, he works as the full professor at the Institute of Forest Inventory and Management at the Faculty of Forestry and Wood Technology, University of Zagreb. He also conducts several courses for undergraduate, graduate, and post-graduate university study programmes.

His main interest and field of works are remote sensing and GIS, aerial imagery interpretation, multi-spectral and hyper-spectral satellite imagery interpretation, spatial data analysis and evaluation, digital cartography, and LiDAR application in forestry.

So far he has published more than 50 scientific and professional papers. He participated at more than 15 national and international conferences. He is also a reviewer for Croatian Journal of Forest Engineering, Šumarski list and other journals in the fields of forestry and remote sensing.

He supervised around 40 Bachelor and Master theses and 2 PhD theses in the field of GIS, Forest Inventory, Remote Sensing and Modelling.

He is member of the Croatian Forestry Society, the Croatian Cartographic Society, and the Scientific Committee for Remote Sensing and Photointerpretation of Croatian Academy of Science and Arts.

Dagmar Haase, PhD

Dagmar Haase is a full professor in urban ecology and urban land use modelling at Humboldt Univeristät zu Berlin in Germany and a Guest Scientist at the Helmholtz Centre for Environmental Research – UFZ. She holds a PhD degree from the Martin-Luther-University of Halle-Wittenberg.

Her main interest and activities include the combination and integration of land-use change modelling and the quantification and assessment of ecosystem services, disservices and socio-environmental justice issues in the cities and urban areas. She works at different spatial scales, from the global to the local and neighbourhood scale.

Conceptually, Dagmar Haase's Lab bases its work on the idea of emergence, resilience, and sustainability of social-ecological coupled systems.

She is the author of over 150 ISI-listed scientific publications.

She also supervised more than 100 Diploma and Master theses and ~25 PhD theses in the field of Landscape Ecology, Land Use Science and Modelling.

In 2010, Dagmar Haase was Fellow of the International Environmental Modelling & Software Society (iEMSs).

In 2014 she received the AXA Award for research on "Resilient Cities".

Since 2015 Dagmar Haase has held the Honorary Wallenberg Professorship of the Swedish Academy of Sciences.

During the last four years, considerable amount of people helped me on my journey to this thesis in front of you. Now it is time for me to say thank you.

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Martina

ABSTRACT

Cultural ecosystem services are part of the concept of ecosystem services and are arguably one of the more important services provided by urban green infrastructure in cities. However, they are non-tangible, subjective and hard to quantify, and therefore rarely fully incorporated into research and decision-making. Ecosystem disservices are a complementary concept in a way that they emphasise negativities people perceive in urban green infrastructure. They are also subjective and therefore hard to assess and quantify. However, their assessment is needed. Online PPGIS (public participation GIS) questionnaire as a spatially explicit method for collecting local knowledge from nonexperts is a proven tool used for collecting data and quantifying perception and use of cultural ecosystem services and disservices. To explore perception and use of urban green infrastructure in relation to cultural ecosystem services and disservices in the city of Zagreb PPGIS questionnaire was designed and implemented. The aim was to collect spatial data about the perception of five categories and associated attributes of cultural ecosystem services and four attributes of disservices of urban green infrastructure along with the respondents' data about socio-demographic characteristics and visiting behaviour to green spaces as non-spatial data. Data analyses included visualisation of collected spatial data, measuring, and calculating spatial metrics on occurrence of cultural ecosystem services and disservices across different types of urban green infrastructure, and statistical analyses of spatial and non-spatial data. In total 384 respondents participated in research by placing 5,757 spatial markers indicating different perception of urban green infrastructure in Zagreb. Twenty different urban green infrastructure types have been defined as providers of cultural ecosystem services and disservices. However, parks, forests, park forests, other green spaces, water features, Botanical garden and the Zoo emerged as hotspots. Even though respondents spatially perceived all attributes of perception, positive perception prevailed in relation to perception of disservices. Differentiation of types of urban green infrastructure based on perception was detected indicating the need for different management practices. Socio-demographic characteristics and visiting behaviour, on the other hand, did not influence the perception to a large extent. With this research new knowledge about different urban green infrastructure types, cultural ecosystem services and disservices emerged, which can be used to enhance planning and management practice in Zagreb in a way that includes public perception.

Keywords: PPGIS, cultural ecosystem services, ecosystem disservices, urban green infrastructure, Zagreb

PROŠIRENI SAŽETAK

KVANTITATIVNA PROCJENA I KARTIRANJE PERCEPCIJE KULTUROLOŠKIH USLUGA I NEGATIVNOSTI URBANE ZELENE INFRASTRUKTURE GRADA ZAGREBA

Današnji svijet je izuzetno urbanog karaktera. Prema dostupnim podacima Ujedinjenih naroda više od pola svjetskog stanovništva može se okarakterizirati kao urbano, dok se u Europskoj uniji postotak urbanog stanovništva procjenjuje na 75%. Prema definiciji, urbanizacija je proces širenja postojećih i nastanak novih gradova koja ujedno uključuje i proces napuštanja ruralnih krajeva i seljenja stanovništva u gradove. Stoga, danas gradovi predstavljaju jedno od najvažnijih mjesta za život ljudi. Pojačana urbanizacija dovodi do promjena u ekološkim procesima, smanjenja bioraznolikosti, klimatskih promjena što za posljedicu ima smanjenje kvalitete života za stanovnike gradova. Urbana zelena infrastruktura predstavlja jedno od mogućih rješenja za navedene probleme i povećanje kvalitete života u gradovima. Svjetska zdravstvena organizacija (WHO) promiče postojanje zelene površine na 300 metara od mjesta stanovanja stanovnika u gradovima što posljedično pozitivno utječe na fizičko i psihičko zdravlje ljudi. Nadalje, brojne politike Europske unije stavljaju naglasak na zelenu infrastrukturu kao instrument za održivo upravljanje gradovima koji kao cilj imaju ugodniji život građana uz smanjenje negativnog utjecaja klimatskih promjena.

Zelena infrastruktura definira se kao strateški planirana mreža prirodnih i polu-prirodnih područja koja su dizajnirana i kojima se upravlja s ciljem provizije širokog spektra usluga ekosustava. Usluge ekosustava je koncept populariziran 2005. godine s izlaskom publikacije Ujedinjenih naroda - Milenijska procjena ekosustava (*Millennium Ecosystem Assessment*) koja temeljem višegodišnjeg rada stručnjaka daje pregled četiri osnovne skupine usluga (usluge opskrbe, usluge podržavanja, usluge regulacije i kulturološke usluge ekosustava). Usluge opskrbe uključuju proizvodnju vode, hrane, drveta i dr., usluge podržavanja uključuju sve procese koji omogućavaju život na Zemlji poput fotosinteze, stvaranja tla, kruženja elemenata, dok usluge regulacije uključuju regulaciju klime, kvalitete vode i regulacije vodenog toka. Zadnja kategorija su kulturološke usluge (*cultural ecosystem services*) koje se definiraju kao nematerijalne koristi koje ljudi dobivaju od ekosustava kroz duhovno obogaćivanje, kognitivan razvoj, refleksiju, rekreaciju i estetiku. Kulturološke usluge obuhvaćaju kulturološku raznolikost, duhovne i religijske vrijednosti, tradicionalne i formalne sustave znanja, edukacijske vrijednosti, inspiraciju, estetske vrijednosti, društvene odnose,

privrženost mjestu, kulturološko nasljeđe te rekreaciju i ekoturizam. Po svojoj definiciji one su nematerijalne, ali iznimno su vrijedne i važne za ljude u urbanim područjima gdje ih pruža urbana zelena infrastruktura. Najčešće se u urbanom prostoru očituju kroz pružanje mogućnosti za rekreaciju i unaprjeđenje estetike prostora. Zbog primarno subjektivnog karaktera, a posljedično i nedostatka univerzalnih varijabli pomoću kojih bi se mogle procijeniti, kulturološke usluge su slabije istražene od preostalih grupa usluga kako na većim tako i manjim prostornim obuhvatima. Prilikom njihovog istraživanje brojne metode se promjenjuju, kvalitativne, kvantitativne, i kombinirane kvalitativne i kvantitativne. Pretpostavka je da su kulturološke usluge među temeljnim razlozima za očuvanje prirode. U gradovima su upravo one glavni razlog za interakciju sa zelenim prostorima jer pružaju mogućnosti za rekreaciju, ali i socijalizaciju. Iako važne, zbog subjektivnosti kojima su karakterizirane i zahtjevne procjene, kulturološke usluge se rijetko procjenjuju i koriste prilikom planiranja i upravljanja urbanom zelenom infrastrukturom u gradovima. Kako bi se procijenile i kvantificirale neophodno je uključiti kako ljude koji ih percipiraju i koriste tako i otkriti koje su to lokacije i tipovi zelene infrastrukture koje prema percepciji korisnika pružaju više od pojedine kategorije kulturoloških usluga.

S druge strane koncepta kulturoloških usluga nalaze se percipirane negativnosti (*disservices*). One su definirane kao funkcioniranje ekosustava koje je štetno po ljudsku dobrobit. Iako ljudi često reagiraju na percipirane negativnosti, one nisu dovoljno istražene niti postoje uvriježene klasifikacije koje omogućuju njihovu implementaciju u planiranje i upravljanje zelenom infrastrukturom. Također, istraživanja pokazuju kako klasifikacije nisu u skladu s onim negativnostima koje korisnici zelenih prostora percipiraju. Korisnici često percipiraju negativnosti koje nastaju zbog ljudskog faktora (neodržavanje zelenih prostora, antropogeno stvorena buka, ponašanje drugih korisnika prostora). Slično kao kod kulturoloških usluga i percipirane negativnosti zahtijevaju kontakt s korisnicima urbane zelene infrastrukture kako bi se istražile jer je njihova percepcija uvjetovana kako karakteristikama korisnika tako i karakteristikama prostora gdje se one stvaraju.

Javni participativni GIS, PPGIS (*Public Participation Geographic Information System*), je proces u kojem se pomoću korištenja GIS tehnologije prikuplja lokalno znanje, odnosno gdje primarno nestručna javnost stvara prostorne podatke koji se potom koriste u planiranju i upravljanju prostorom. Prostorno eksplicitne metode poput PPGIS upitnika omogućavaju da se subjektivnim konceptima poput kulturoloških usluga i negativnosti da prostorna

komponenta koja potom omogućava njihovu kvantifikaciju, vizualizaciju i analizu onih čimbenika koji utječu na njihovu pojavu u prostoru.

U Hrvatskoj se još nije koristio PPGIS upitnik kao metoda prikupljanja prostornih podataka o percepciji i korištenju kulturoloških usluga i negativnosti urbane zelene infrastrukture. Pritom postoji potreba za dodatnim istraživanjem navedenih koncepata. Sami koncepti su slabije istraženi kako u Hrvatskoj, tako i u gradu Zagrebu koji je administrativno, političko i ekonomsko središte Republike Hrvatske, a ujedno i najveći grad kojem gravitira brojne stanovništvo. Ovo istraživanje koje je za cilj imalo kvantificirani percepciju kulturoloških usluga i negativnosti urbane zelene infrastrukture u gradu Zagrebu provedeno je u sklopu projekta Hrvatske zaklade za znanost „Unaprjeđene planiranja i gospodarena zelenom infrastrukturom kroz participativno mapiranje kulturnih usluga ekosustava (CULTUR-ES)“ (UIP-2017-05-1986) pod vodstvom dr. sc. Silvije Krajter Ostoić na Hrvatskom šumarskom institutu.

Na temelju rezultata dosadašnjih istraživanja zelenih prostora grada Zagreba kao i rezultata inozemnih istraživanja pojavnosti kulturoloških usluga i negativnosti na većim i manjim prostornim obuhvatima za ovo istraživanje postavljene su sljedeće hipoteze.

H1: Kulturološke usluge i negativnosti nisu nasumično raspoređeni unutar urbanog krajobraza već je njihovo pojavljivanje u ovisnosti o tipu urbane zelene infrastrukture,

H2: Percepcija i korištenje kulturoloških usluga i negativnosti urbane zelene infrastrukture ovisi o sociodemografskim karakteristikama ispitanika, tipu urbane zelene infrastrukture, općenitim navikama korištenja, udaljenosti od doma i urbano-ruralnom gradijentu.

METODOLOGIJA RADA

Za potrebe ispitivanja predloženih hipoteza ovoga rada korišten je PPGIS upitnik (*MyDynamicCity* Zagreb) s ciljem kartiranja, procjene i kvantifikacije percepcije kulturoloških usluga i negativnosti urbane zelene infrastrukture grada Zagreba od strane njegovih stanovnika.

Internetski PPGIS upitnik dizajniran je i prilagođen prostornom kontekstu grada Zagreba na *MyDynamicCity* Internetskoj aplikaciji. Internetski upitnik je postavljen na server Hrvatskog šumarskog instituta s domenom kartirajzelenilo.sumins.hr. Upitnikom su prikupljani prostorni podaci u točkastom obliku o percepciji pojavnosti pet kulturoloških usluga i negativnosti u

zelenim prostorima grada Zagreba. Prostorni podaci koji su prikupljani bili su: kvadrant s adresom stanovanja ispitanika, lokacije privrženosti mjestu, lokacije korištene za različite rekreativne aktivnosti, lokacije atributa estetike i percipiranih negativnosti, lokacije edukacije u urbanoj zelenoj infrastrukturi i lokacije koje nose kulturni identitet. Za rekreaciju i estetiku sudionici istraživanja su mogli odabrati one atribute koji su njima bitni čime se dodatno istražila percepcija tih kategorija kulturoloških usluga. Ponuđeni atributi rekreacije bili su bicikliranje, šetnja, trčanje, planinarenje, promatranje prirode, odlazak van s djecom, šetnja psa i socijalizacija, dok su atributi estetike bili uređeno, opuštajuće, prirodno i estetski lijepo. Sudionici su također imali mogućnost kartirati i negativnu percepciju kroz ponuđene atribute negativnosti (neuredno, bučno, strašno i lokacije gdje se konflikti s drugim korisnicima događaju) u istom pitanju s atributima estetike,. Ostali prikupljani podaci uključivali su sociodemografske karakteristike sudionika kao i njihove uobičajene navike posjećivanja zelenih površina u Zagrebu.

Definirani uzorak ispitanika za ovo istraživanje bio je 384, koristio se neprobabilistički uzorak ispitanika, a prilikom distribucije upitnika i prikupljanja podataka koristili su se različiti načini pronalaska sudionika (kontakti mjesnim odborima, udrugama građana, stručnjacima, oglašavanje putem društvenih mreža i *newslettera*, sudjelovanje na konferencijama, osobni kontakti i drugi).

Vizualizacija prikupljenih prostornih podataka, mjerenje i računanje prostornih metrika kao i statističke metode na prostornim i ne-prostornim podacima korišteni su za testiranje postavljenih hipoteza za ovaj rad.

REZULTATI

U PPGIS upitniku *MyDynamicCity* Zagreb ukupno je sudjelovalo 389 sudionika čiji je broj smanjen na 384 nakon što su iz baze maknuti dupli unosi te oni sudionici čije karakteristike ne zadovoljavaju kriterije sudjelovanja (maloljetnici ili sudionici koji ne žive u gradu Zagrebu). Ukupno je upitnikom prikupljeno 6673 prostornih markera kojima je označena prostorna percepcija kulturoloških usluga i negativnosti, no taj je broj reduciran na 5757 kada su se iz analize maknule one točke koje nisu bile postavljene unutar granica grada Zagreba i definiranih tipova urbane zelene infrastrukture.

Kombinacijom vektorskih baza podataka (način korištenja zemljišta te katastar zelenila ustupljeni na korištenje od strane Grada Zagreba) stvorena je sekundarna vektorska baza podataka na kojoj je napravljena klasifikacija urbane zelene infrastrukture grada Zagreba. Klasifikacijom je definirano 20 različitih tipova urbane zelene infrastrukture u gradu Zagrebu.

Analizom prikupljenih prostornih podataka u odnosu na klasifikaciju urbane zelene infrastrukture u gradu Zagrebu otkriveno je kako su parkovi, šume, park šume, ostale zelene površine (neuređeno, agrikulturno ili zaštitno zelenilo), zelenilo oko vodenih elemenata i Botanički/Zoološki vrt tipovi s najviše prikupljenih prostornih markera te koji se ističu u gradu Zagrebu. Kartografski prikazi rezultirali su s detaljnijim prikazima onih lokacija koje su prema percepciji građana grada Zagreba jače percipirane kao pružatelji određene kategorije kulturoloških usluga ili negativnosti. Parkovi Maksimir, Bundek i Jarun, Medvednica, prostor ornitološkog rezervata Savica, nasip uz rijeku Savu kao i Botanički vrt te parkovi i park šume u centru grada pojavili su se kao prostori gdje su pojedine kategorije kulturoloških usluga i negativnosti jače percipirane. Mjerenjem udaljenosti postavljenih markera za pojedinu kategoriju i atribut te njihovom međusobnom usporedbom dobili su se vrijedni rezultati o tome koliko daleko se pojedina usluga ili negativnost percipira. Lokacije označene za planinarenje, koje se doživljavaju prirodnima udaljenije su od doma ispitanika dok su lokacije na kojima se percipiraju negativnosti najbliže domu ispitanika kao i one lokacije koje se koriste za rekreativne aktivnosti trčanja ili šetnje psa.

Faktorskom analizom dobiveni su podaci o međuodnosu pojedinih tipova urbane zelene infrastrukture i percepcije koju građani Zagreba imaju o njima. Šume su izdvojene kao lokacije za planinarenje i promatranje prirode te koje se doživljavaju prirodima. Parkovi se percipiraju kao uređene lokacije gdje se ljudi socijaliziraju koje su ujedno nositelji edukacijskog potencijala i kulturnog identiteta, dok se u blizu vodenih površina i na ostalim zelenim površinama pronalaze i svakodnevne aktivnosti i percipirane negativnosti. Analizom urbano-ruralnog gradijenta definirale su se gradske četvrti u kojima nedostaje kvalitetne zelene infrastrukture i one kojima ljudi iz tih gradskih četvrti gravitiraju.

Analizom utjecaja sociodemografskih karakteristika ili uobičajenih obrazaca korištenja zelenih površina nisu se pronašle značajne razlike u percepciji i korištenju urbane zelene infrastrukture.

ZAKLJUČAK

Kartiranjem percepcije kulturoloških usluga i negativnosti urbane zelene infrastrukture grada Zagreba dobili su se vrijedni podaci od strane građana Zagreba koji se mogu koristiti prilikom njenog planiranja i upravljanja. Uspješna implementacija PPGIS upitnika predstavlja novu mogućnost participacije javnosti u pitanjima o planiranju prostora, ali uz devijaciju karakteristika sudionika istraživanja od prosjeka populacije. Percepcija javnosti o zelenoj infrastrukturi je uglavnom pozitivna, ali negativna percepcija je također kartirana označavajući lokacije na koje treba obratiti pozornost kao i atribute negativne percepcije koji se snažnije primjećuju u urbanoj zelenoj infrastrukturi. Diferencijacija u percepciji i načinu korištenja urbane zelene infrastrukture može pomoći definiranju kvalitetnijeg upravljanja određenim prostorom s ciljem isticanja njegovih poželjnih karakteristika i smanjenja negativnih. Ovo je prvo istraživanje ovakvoga tipa u Hrvatskoj čime se otvara mogućnost implementacije ovakvih i sličnih istraživanja u drugim prostornim kontekstima. Pojedini rezultati ovoga istraživanja otvaraju nova istraživačka pitanja na kojima se mogu temeljiti buduća istraživanja urbane zelene infrastrukture u gradu Zagrebu.

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1. INTRODUCTION

One of the most significant traits of today's world is urbanisation. The process of urbanisation is characterised by expanding the existing and creating new cities to which people move, predominantly from rural areas. Based on the current data, more than half of the world's population is considered urban, while around 75% of EU population lives in cities (UN, 2019). Projections state that this number will further increase on a global scale. Cities, therefore, represent one of the most important habitats for people. However, continuing urbanisation holds numerous threats and pressures on ecological processes, biodiversity, and the well-being of residents in the cities. Cities of today are already facing numerous problems such as climate change, demographic issues, gentrification, natural resource reduction and more. These existing problems led to the increased attention given to the green infrastructure such as forests and parks, but did not confine only to them, as a potential help in creating sustainable cities at the European level (Konijnendijk et al., 2005). Green infrastructure regardless of being natural or semi-natural is seen as a potential solution to some of the mentioned problems (EC, 2013). Furthermore, World Health Organisation (WHO) promotes the need of having accessible green areas inside cities as is highly beneficial for citizens' physical and mental health and subsequently their well-being (WHO, 2016). Quality green spaces are fundamental for improved quality of life in the cities.

Cities are complex systems where built environment such as buildings and roads, known as the grey infrastructure, is interconnected with patches of nature or nature-like spaces such as parks and forests that are usually referred to as urban green spaces. Urban green spaces provide plentiful of benefits which consequently, directly, and indirectly, improve the quality of life for people living in cities. Moreover, urban green spaces are usually the only places where city dwellers can experience nature (Riechers et al., 2016). All benefits provided by the ecosystems are commonly called ecosystem services, and when they are produced in urban areas, they become urban ecosystem services (Haase et al., 2014). Broadly defined, ecosystem services are all benefits provided to the people by different ecosystems. The term has been mainstreamed with the publishing of the Millennium Ecosystem Assessment (MEA), United Nations' publication in 2005 (MEA, 2005). MEA describes four main categories of ecosystem services: *supporting*, *provisioning*, *regulating* and *cultural* ecosystem services. Supporting services support life on Earth through functions such as photosynthesis, soil formation, and nutrient cycling; provisioning services include production of food, water, timber, and fibre;

regulating services are expressed through climate regulation, along with regulation of floods, diseases, water quality and more; while cultural services provide recreational, aesthetic and spiritual benefits to humans (MEA, 2005).

Significant amount of research was conducted in the field of ecosystem services and green spaces. A comprehensive overview on the topic of ecosystem services production by urban green spaces has been presented by Haase et al. (2014). The terms ecosystem services and green infrastructure are interconnected and usually make a comprehensive unit. There is an overarching need for cities of tomorrow to be sustainable and resilient to contend with climate change and the related negative effects. Hence, the concept of ecosystem services is used as a basis for sustainable development, especially in the European Union (EU). The EU is developing the concepts of ecosystem services and green infrastructure to guide the actions aimed at increasing the sustainability and resilience of the cities throughout the EU, as well as at enhancing the quality of life of its citizens. In that regard European Commission (EC) defined green infrastructure as a "*strategically planned network of natural and semi-natural areas with other environmental features designed and managed to deliver a wide range of ecosystem services*" (EC, 2013). Green infrastructure is therefore an important part of the sustainable development used to reach proposed resilience goals in the European cities (Andersson et al., 2015; Riechers et al., 2016; Tandarić et al., 2020).

The importance of sustainable cities and urban green spaces was further emphasised in 2015 with United Nations' Sustainable Development Goals (UN-SDG) (UN, 2015). There are 17 goals in total, and one of them is specifically aimed at sustainability of the cities – Goal no. 11 – 'Making cities inclusive, safe, resilient and sustainable'. Goal no. 11 has 10 defined targets aimed at different aspects of sustainable development of the cities such as: enhancing inclusive and sustainable urbanisation, reducing environmental impact of cities with attention to air quality and waste management, safeguard the world's cultural and natural heritage, and more. In the context of this work, the most important target is aiming at providing universal access to safe, inclusive, and accessible, green, and public spaces, in particular for women and children, older persons and persons with disabilities (UN, 2015). In the sense of UN-SDG, trees, and urban green spaces play an important role, and based on the review by Turner-Skoff and Cavender (2019), trees can help in meeting 15 out of 17 UN-SDG goals for the cities and communities directly or indirectly.

Since urban green spaces and trees are increasingly highlighted as important in different concepts and strategies, urban forestry provides valuable concepts, approaches and disciplines that can be utilised in reaching the above-mentioned goals. Even though, the term 'urban forestry' is still a bit ambiguous; one of the most often cited definition is that *"urban forestry embodies a multidisciplinary approach to the planning and management of all forest and tree resources ranging from street trees to peri-urban woodlands - in and near urban areas"* (Konijnendijk et al., 2005). This definition confirms the suitability of the urban forestry concept as a beneficial approach that integrates all the necessary components of managing urban green spaces to reach sustainability goals of the cities. Also, scientific work in the field of urban forestry worldwide is heavily interconnected with the concepts of ecosystem services, management, urban planning, and green infrastructure (Krajter Ostoić and Konijnendijk van den Bosch, 2015).

1.1. Cultural ecosystem services

The concept of ecosystem services as we know it today has emerged from a long-term assessment of all the benefits that ecosystems provide to the people. While all services are inherently important for human well-being, on a global scale they are all in decline (MEA, 2005). When taking into consideration the share of people living in urban areas, cultural ecosystem services are emerging as undoubtedly important for city dwellers. Especially, because once lost, they are usually impossible to replace, and based on the MEA assessment significant amount of them (around 70%) are being degraded or used unsustainably, therefore leading to serious harm to human well-being. (MEA, 2005). There is also much evidence that cultural ecosystem services are the main reason for ecosystem consideration and to some extent an underlying foundation for all ecosystem services' frameworks (Hernández-Morcillo et al., 2013).

"*Cultural ecosystem services (CES) are the nonmaterial benefits people obtain from ecosystems through spiritual enrichment, cognitive development, reflection, recreation, and aesthetic experiences*". They include cultural diversity, spiritual and religious values, knowledge systems (traditional and formal), educational values, inspiration, aesthetic values, social relations, sense of place, cultural heritage values, and recreation and ecotourism (MEA, 2005). Building on this widely used definition, cultural ecosystem services are primarily non-tangible, subjective and person-specific. In relation to other ecosystem services (provisioning,

regulating, and supporting), cultural ecosystem services are the most difficult to assess and study, therefore they are the least explored (Cheng et al., 2019). Additionally, they are heavily influenced with the cultural context out of which they emerge and the characteristics of beneficiaries, hence it is hard to develop universal indicators to assess them (Hernández-Morcillo et al., 2013). Even though cultural ecosystem services have been discussed in the scientific literature before, under different names and terminology, MEA classification mainstreamed these services into scientific work (Milcu et al., 2013).

Various research explored non-material values and benefits that ecosystems provide to humans employing different typologies, but in their essence all these values could be put under the umbrella term of – cultural ecosystem services (Brown et al., 2015a). Some of the developed typologies are landscape values (Alessa et al., 2008), landscape services (Fagerholm et al., 2012), social values for ecosystem services (Sherrouse et al., 2011). These typologies do not represent the complete overview, but rather a subset of different methodological approaches and terminology used while developing cultural ecosystem services' research field as it is. Today, field of research developed around cultural ecosystem services assessment is characterised with interdisciplinarity, more defined typology than before, and more sophisticated methodological approaches to data collection and analysis.

Constant increase in the number of scientific papers dealing with cultural ecosystem services in various spatial and cultural contexts has been evidenced since 2005, which is coincidentally the year MEA was published (Cheng et al., 2019). Still, cultural ecosystem services are rarely incorporated into planning and management processes even though they are arguably often the underlying reason for nature protection and conservation (Milcu et al., 2013). Their characterization as intangible, subjective or hard to assess prevents their translation into urban planning and management (Hernández-Morcillo et al., 2013; La Rosa et al., 2016; O'Brien et al., 2017). There are also other constraints that hinder their implementation into planning and management. Some authors stress methodological and conceptual challenges that often accompany the concept (O'Brien et al., 2017). One of the more important constraints relates also to their assessment and valuation since methodological consistency still does not exist (Hernández-Morcillo et al., 2013). In that regard, more than 20 different methods have been applied to valuation of cultural ecosystem services in diversity of studies (Cheng et al., 2019). Different approaches have been applied to cultural ecosystem services assessment. Quantitative and qualitative research methods have been used with the aim to understand different aspects of cultural ecosystem services' perception and provision. Qualitative methods

help to identify and understand the specifics of cultural ecosystem services' perception and use, alongside exploring their complexities in different environments. Quantitative methods employed often try to assess and quantify cultural ecosystem services in monetary or non-monetary terms (Cheng et al., 2019). Qualitative, quantitative and mixed-methods have all been used in cultural ecosystem service assessment and valuation with different goals and results (ibid.).

Because of assessment and valuation issues, the concept of ecosystem services has gone through some changes from its original form (Dickinson and Hobbs, 2017). Other classifications emerged later such as CICES (Common International Classification of Ecosystem Services) or TEEB (The Economics of Ecosystems and Biodiversity) with the goal of efficient introduction of ecosystem services, including cultural ecosystem services, into governance through e.g., monetary valuation. However, MEA classification remains the one usually used for cultural ecosystem services research in urban areas (Cheng et al., 2021). Based on empirical research MEA classification is mostly concordant with perceptions and experiences that citizens express in relation to green spaces in the cities (Riechers et al., 2016). Acknowledging the benefits that citizens gain from urban green spaces can help in advancing management practice in a way that is ecologically acceptable and aimed at promoting and enhancing further the concept of cultural ecosystem services. Otherwise, it could provoke community's reaction when management actions degrade the provision of cultural ecosystem services in some area (Andersson et al., 2015).

In an urban context, cultural ecosystem services are among those easily perceived and highly valued by citizens. They are arguably the most important ecosystem services in urban areas (Kremer et al., 2016). Given that urban green spaces are usually the only places where people can develop meaningful human-nature interaction, out of which cultural ecosystem services emerge, their evaluation is necessary (Dickinson and Hobbs, 2017). Providers of cultural ecosystem services in an urban environment are different types of green spaces. Green spaces are often referred to as the green infrastructure. European legislative has defined green infrastructure also as *"the network of natural and semi-natural areas, features and green spaces in rural and urban terrestrial, freshwater, coastal and marine areas"* (Naumann et al., 2011). The definition of the term emphasises its broadness since green infrastructure could include natural and man-made feature respectfully. Natural areas refer to parks, forests, hedgerows, wetlands, marine areas (ibid.). Urban green infrastructure (UGI) is the term used for green infrastructure placed in cities. One of the most important tasks of the green

infrastructure is to deliver multiple benefits and functions. Multifunctionality, often attributed to green infrastructure is largely important in urban areas where different elements of green infrastructure need to provide all ecosystem services to city dwellers. However, spreading of the cities usually occurs on natural and unbuilt terrains, sometimes parts of the green infrastructure, therefore reducing the available area for delivering ecosystem services, including cultural. Diverse and functional green spaces help cities to become liveable places. Everlasting need for new building land, on the other hand, is putting pressure on the existing green spaces. Green infrastructure often competes with other infrastructure for space (Andersson et al., 2015).

Hereof, while cultural ecosystem services are arguably more meaningful to people than other services (Tandarić et al., 2020), they usually demand direct contact with ecosystem for service to be perceived. Therefore, cultural ecosystem services could be further seen as the main reason why people interact with urban green spaces (Bertram and Rehdanz, 2015; Hegetschweiler et al., 2017; Ko and Son, 2018). Furthermore, some studies emphasise recreation as an underlying goal for green interventions and purposeful human-nature interaction (Krajter Ostoić et al., 2020a; Riechers et al., 2016).

Even though the cultural ecosystem services are important for quality of life expressed through, among others, better physical and mental health of citizens (Ode Sang et al., 2016), there are not many studies that systematically cover the topic of cultural ecosystem services' provision in urban green spaces. When they do, those categories of cultural ecosystem services which are easier to distinguish and quantify are more explored, such as recreation, ecotourism, and aesthetics, while intangible, more subjective ones are excluded (Cheng et al., 2019). Furthermore, when conducted, research on cultural ecosystem services provided by urban green spaces is not equally distributed worldwide. Europe is a leader in conducting research on cultural ecosystem services and urban green spaces with Germany and United Kingdom being the most active countries followed by research from Asia and North America (Vidal et al., 2022). Given that the concept of ecosystem services is highly used in EU legislative it is not a surprise that cultural ecosystem services are mostly studied there. Additionally, literature reviews of different aspects of cultural ecosystem services in urban green areas are usually rather scarce with literature on the topic (Hegetschweiler et al. (2017) - 40 papers, Cheng et al. (2021) - 67 papers, Vidal et al. (2022) - 41 papers). This indicates that more empirical research in the field of cultural ecosystem services provided by urban green areas is needed to better understand how important these spaces and services are to the urban population. However, in

the last 20 years, an increase in the research conducted in the field of cultural ecosystem services can be noticed (Cheng et al., 2019). This could partly be due to the implementation of participatory tools such as PPGIS (public participation geographic information system) that allow in-depth, spatially accurate exploration of the phenomena that are person-specific such as cultural ecosystem services. These tools allow the integration of surveys and place-based research that grant various statistical analyses on the gathered data, therefore making cultural ecosystem services more quantifiable (Ridding et al., 2018).

Spatial and socio-demographic heterogeneity of the urban spaces make assessment and evaluation of cultural ecosystem services challenging and sometimes complicated (Rall et al., 2017). Spatial heterogeneity is characterized by diversity of UGI types that can be found in cities. It is not strange that research on cultural ecosystem services more often takes place on a landscape level where it is easier to delineate different characteristics of landscape using various spatial metrics or existing datasets e.g., land use/land cover (LU/LC) (Ridding et al., 2018). Datasets on LU/LC for larger areas are usually readily available online, ready to be integrated with collected spatial data on cultural ecosystem services and easier to interpret (Fagerholm et al., 2021a). On the other hand, in urban areas large number of LU/LC types are present and interconnected, with datasets often not readily available and challenging to interpret in relation to cultural ecosystem services, posing particular challenge for researchers and experts alike (La Rosa et al., 2016). Cultural ecosystem services are more readily experienced in urban areas through interactions with urban nature which makes them substantial for city dwellers, while benefits people obtain as a result from human-nature interaction make cultural ecosystem services recognized in relation to other ecosystem services (Andersson et al., 2015). Spatial heterogeneity is not only represented in diversity of green infrastructure types that provide cultural ecosystem services to people but also in heterogeneity of biophysical attributes that make urban green spaces. Furthermore, heterogeneity of the characteristics of people using UGI makes the assessment of these services and their benefits challenging, but necessary (Dickinson and Hobbs, 2017).

Due to the above-mentioned heterogeneity in the composition and types of UGI and strong human impact, cultural ecosystem services are unique for a given location. Commonly explored types of urban green infrastructure might not be sufficient to grasp the wholeness of the provided and experienced cultural ecosystem services in urban areas (Dickinson and Hobbs, 2017). Also, studies rarely provide much detail about the UGI type in locations where research

is conducted (O'Brien et al., 2017). More comprehensive knowledge about the interaction between different types of UGI and cultural ecosystem services is needed.

On the other hand, spatially explicit research of cultural ecosystem services' perception on a landscape level indicates that distinct land cover types provide more of the specific services. Usually, urban areas are associated with provision of predominantly cultural and social values (Fagerholm et al., 2016; Garcia-Martin et al., 2017; Jaligot et al., 2019; Plieninger et al., 2013), while forests and water features are perceived as providers of aesthetic services, outdoor recreation, and to some extent education (Garcia-Martin et al., 2017; Jaligot et al., 2019; Plieninger et al., 2013). When it comes to cultural ecosystem services' perception and use on a landscape level then accessibility, closeness to urban areas, larger forest areas and areas that are historically important are found to be influential (Ridding et al., 2018). Research on the perception and use of cultural ecosystem services in a wide city areas of Madrid and Budapest further confirms perception and use patters from landscape research with urban fabric providing significant amount of historic and educational values (Valánszki et al., 2022) and where forests are highly associated with recreation and aesthetic experiences (García-Díez et al., 2020; Valánszki et al., 2022). Both studies also emphasise the importance of local green infrastructure such as parks, urban forests and tree alleys located near or in the city centres as highlighted providers of the diversity of cultural ecosystem services (ibid.). However, details about the type of UGI providing those services have not been explored.

Detailed research in different UGI types with regard to provision of cultural ecosystem services exists, but it is usually concentrated on a single UGI type or a single location with an exception found in Beichler (2015) and Rall et al. (2017), where city-wide coverage of different cultural ecosystem services can be found, however, without referring to specific UGI. Also, Krajter Ostoić et al. (2020a) have qualitatively studied cultural ecosystem services in relationship with different tree-based UGI types on a city level. Riechers et al. (2019) explored urban-rural gradient in perception of cultural ecosystem services through interrelation of perception, population density, and some UGI types. Ives et al. (2017) examined manifestation of cultural ecosystem services in differently managed green spaces in Australia, while Pietrzyk-Kaszyńska et al. (2017) explored non-monetary values of formal and informal green spaces in three Polish cities. More focused research on the perception and use of cultural ecosystem services has been conducted for urban forests (Baumeister et al., 2020; Beckmann-Wübbelt et al., 2021; Gerstenberg et al., 2020; Korpilo et al., 2018); parks (Bertram and Rehdanz, 2015; Brown et al., 2014; Chiesura, 2004; Vierikko et al., 2020), urban stream corridors (Garcia et

al., 2017), as well as on neighbourhood green space (Säumel et al., 2021) and brownfields (Palliwoda and Priess, 2021). Based on findings from the mentioned studies there is an indication that differences in the perception and use of different UGI types exist, but empirical evidence for this is still lacking. Scientific literature highlighted the need for more research on diversity of UGI types, especially those less often explored (O'Brien et al., 2017). Previous research has also shown that perception of cultural ecosystem services could change along the urban-rural gradient (Rall et al., 2017; Riechers et al., 2019), and would be related to distance from the respondent's home, which proved influential on the perception and use of cultural ecosystem services (De Valck et al., 2016; Fagerholm et al., 2019; Lehto et al., 2022).

Human-nature interactions are becoming relevant for both research and practice dealing with urban green spaces and cultural ecosystem services (Kabisch et al., 2015; Tandarić et al., 2020). Meaningful human-nature interactions usually occur at locations where supply and demand factors are met (Hegetschweiler et al., 2017). These interactions are crucial because they strengthen the relationship people have with the ecosystem and subsequently sustain behaviours aimed at nature and environment protection (Ives et al., 2018). Furthermore, these behaviours can help the city to become resilient and sustainable, contributing in the long run to numerous global goals for sustainable development (Chiesura, 2004). Cultural ecosystem services are heavily dependent not only on physical space providing them and people perceiving them, but also the time in which this interaction takes place (Blicharska et al., 2017). Understanding the ways in which people and green spaces interrelate with each other can enhance our knowledge and comprehension of importance of urban green spaces to city dwellers. Research shows how cultural and socio-demographic background of respondents influences the perception of cultural ecosystem services (Bieling et al., 2014; Fischer et al., 2018; Kabisch et al., 2015; Ode Sang et al., 2016; Plieninger et al., 2013; Riechers et al., 2018), but also their visiting behaviours (Bertram et al., 2017).

Participatory approaches, and specifically participatory mapping, are highlighted as effective and sometimes favourable approaches to exploring cultural ecosystem services (Brown and Fagerholm, 2015). Indeed, participatory mapping offers additional approach to standard expert-based assessments of cultural ecosystem services as it includes spatially explicit perception of direct users and beneficiaries of these services (ibid.). It is beneficial to include perception and use of those who directly benefit from these services to complement expert-based assessments and to achieve functional and acceptable management (Blicharska et al., 2017; Dickinson and Hobbs, 2017).

1.1.1. Cultural ecosystem services research in Croatia

The concept of ecosystem services in Croatia is still rather unfamiliar. However, the assessment and mapping of ecosystem services for the whole area of Croatia based on the most important land cover types exists (AZO, 2015). Specifically, the term of *cultural ecosystem services* is not well utilised and is seldom studied in a scientific literature as such. Nevertheless, research in urban green spaces exists. Recent extensive review of scientific literature on urban forestry and green spaces research in Croatia and Slovenia in the last three decades discovered that there is a significant amount of work being published in these research areas in both countries (Krajter Ostoić et al., 2020b). For Croatia, specifically, most of the research is conducted in Zagreb and Zagreb's green infrastructure covering a wide array of research themes. Among those, public perception was addressed in little over 10% of all papers studied when research was conducted in Zagreb with survey questionnaire being data collection method of choice. The same review also indicated that there is rarely more than one study site in addressed papers, meaning that complete information about perception of different green areas in the cities in Croatia, or in Zagreb respectively, is still missing. Furthermore, parks are predominantly the most explored types of green spaces in Croatia, leaving significant gap in understanding different aspects of other green space types (Krajter Ostoić et al., 2020b).

Among the most important works on the topic of perception of urban green spaces in Croatia and Southeast European countries is the cross-country research on citizens' perception and satisfaction with urban green spaces done by Krajter Ostoić and colleagues (2017). By using survey questionnaire the research included citizens of seven cities in southeast Europe. Important results of this research are that perception and satisfaction vary among citizens of cities engaged in research, but that citizens regardless of city or country find urban green spaces important. On the other hand, this does not mean that they do not perceive problems or express dissatisfaction with some aspects related to green spaces.

Moreover, the first study in Croatia that combined the terms of cultural ecosystem services and green spaces was done for the tree-based urban green spaces in Zagreb. The perception of cultural ecosystem services was explored by conducting focus groups with citizens in the city of Zagreb (Krajter Ostoić et al., 2020a). Focus group interviews were held in Zagreb's 17 city districts with residents of the respective districts where in total 94 participants took part. Focal points of these interviews were tree-based urban green spaces inside particular city district boundaries and how they are perceived in relation to different categories of cultural ecosystem services. Results showed, in accordance with other research, that some categories of cultural

ecosystem services are more (easily) perceived than others. Those categories were place attachment, recreation, and aesthetics, while cultural identity and education were less perceived in relation to attributes given, as well as the types of green spaces attached to providing these services to participants (Krajter Ostoić et al., 2020a). Furthermore, overlaps between the categories of cultural ecosystem services were detected, meaning that sometimes the same green space type can be perceived as the provider of multiple cultural ecosystem services. The results of this research are important because they pose a qualitative background for quantification of cultural ecosystem services. Building on qualitative research before quantification is a highly useful approach and often called for in scientific literature on research of cultural ecosystem services (Dickinson and Hobbs, 2017).

Cultural ecosystem services and their connection with UGI in Zagreb is still a rather underexplored topic in scientific literature in Croatia. Except the afore-mentioned qualitative study which resulted in attributes of perception in relation to different types of tree-based urban green spaces there is no more research on the topic (Krajter Ostoić et al., 2020b). In order for cultural ecosystem services to be further integrated into scientific work and perhaps into planning and management practice in Croatia, more research is needed. It is argued that quantification of cultural ecosystem services' provision could help improving addressing and communicating rather subjective and usually intangible benefits to relevant stakeholders (Cheng et al., 2021). Hence, quantification of cultural ecosystem services provided by UGI for the city of Zagreb is a novel task which will results in new information about the perception and use of different green spaces by different users and enhance understanding of the role that urban green spaces have for citizens. In an informed decision-making process assessment of the relationship between management and ecosystem services is important since it allows addressing trade-offs that emerge from land cover or land use change (Haase et al., 2014). One possible method for addressing potential trade-offs is to visualize the current spatial distribution of landscape functions and values (de Groot et al., 2010).

1.2. Ecosystem disservices

Alongside the provision of various ecosystem services, UGI can likewise be perceived as a provider of negative features. These negative features, or 'bad' aspects, are labelled as ecosystem disservices (Lyytimäki, 2017). Concept of ecosystem disservices emerged recently, shortly after the concept of ecosystem services, but to this day disservices are not emphasised

in research and in practice as much as their 'positive' counterparts. This is partly because the widely agreed definition of the term itself is still non-existing, and consequently there are no commonly used classifications or comprehensive conceptual frameworks to work with (Lyytimäki, 2017; Shackleton et al., 2016; von Döhren and Haase, 2015). These issues are regularly emphasised as the main barriers towards inclusion of ecosystem disservices into research and policy (Blanco et al., 2019). Many authors argue that ecosystem services and disservices are not opposite terms, rather that they co-exist and need to be assessed as such (Haase et al., 2014; Shackleton et al., 2016). Therefore, the main aim of the concept of disservices is not to oppose the concept of ecosystem services, but to provide balance in their assessment complementing positive traits perceived in UGI with those that are perceived negative (Lyytimäki, 2017). In this research ecosystem disservices are understood in a broad sense as "*ecosystem services perceived negative for human well-being*" referring to a definition proposed by Lyytimäki and Sipilä (2009). This is the first definition given to the term; later new definitions emerged, out of which the most used is the one proposed by Shackleton et al. (2016) stating that "*ecosystem disservices are the ecosystem generated functions, processes and attributes that result in perceived or actual negative impacts on human wellbeing*". Common characteristics of disservices in both definitions are that they originate from the ecosystem and that they are manifested mainly in social-ecological system (Lyytimäki, 2017). Ecosystem disservices can originate from any ecosystem regardless of man's influence on it (Shackleton et al., 2016). Second issue regularly associated with ecosystem disservices is linked to categorisation of disservices. Authors in the respective fields of ecosystem services and disservices stress that developing applicable categorisation of different disservices could facilitate their implementation into research and practice, so further development of such framework is posed as a necessity (Blanco et al., 2019). That does not mean that there are no frameworks developed, but they are still not widely used. To test and develop such frameworks more research in the field of ecosystem disservices needs to be done across different social-ecological systems (Blanco et al., 2019). Because of conceptual and methodological issues associated with ecosystem disservices, research on disservices and urban green spaces is still relatively scarce despite their frequent manifestation in urban areas (O'Brien et al., 2017; Shackleton et al., 2016). Ecosystem disservices have indeed been more often explored in an anthropogenically affected ecosystems such as agricultural landscapes and urban spaces (Shackleton et al., 2016). Mostly because the concept of ecosystem disservices is much like the concept of cultural ecosystem services highly dependent on human perception and therefore is primarily manifested in social-ecological systems (Lyytimäki, 2017). Based on that, the

perception of disservices is highly influenced by the beneficiaries and their characteristics (socio-economic, cultural, and other). Some things that can be seen as positive in one case and providing ecosystem services, oftentimes could also be seen as negative by someone else and vice versa (Shackleton et al., 2016).

Nevertheless, research on ecosystem disservices exists and is steadily gaining momentum (Baumeister et al., 2022; Blanco et al., 2019; von Döhren and Haase, 2015). Conclusion based on a literature review produced by von Döhren and Haase (2015) is that research on ecosystem disservices is primarily conducted in Europe and North America, similar to geographical distribution of ecosystem services' research. The review also discovered that the majority of papers on the topic of ecosystem disservices did not include spatial component even though the concept is place-dependent, hence the concept was only discussed and not proved. Likewise, scientific work on ecosystem disservices by urban trees more often discussed the concept of disservices in relation to urban trees than demonstrated it (Roy et al., 2012).

In general, usual proxies used when demonstrating the ecosystem disservices are those related to biophysical characterisation of disservices, e.g. releasing volatile organic compounds, economical characterisation expressed through generated costs and social/cultural characterisation. Whereby using interviews the description of ecosystem disservices is given. Negative effects of ecosystem disservices on human well-being are manifold. They range from effects onto ecological systems which hinder provision of ecosystem services, onto human physical and mental health to negative effects expressed in monetary terms (von Döhren and Haase, 2015).

Combined assessment of ecosystem services and disservices could be beneficial for policy-makers, decision-makers, and other relevant stakeholders in urban green spaces. Trade-offs among services and disservices could then be assessed, leading to more informed management (Haase et al., 2014; Lyytimäki, 2017). It is argued that assessment of disservices could actually enhance our understanding of ecosystem services by providing complementary viewpoint where trade-offs among ecosystems and quality of life could be examined (Haase et al., 2014). On the other hand, just like cultural ecosystem services, disservices are also heavily context-dependent, and their perception is influenced by social-ecological system where they are produced (ibid.).

Some authors stress that the assessment of exclusively ecosystem services (benefits) can produce a wrong idea that all ecosystems are naturally 'good' and beneficial, when the case is

that more often there are trade-offs among services and disservices (Roman et al., 2021). On the other hand, even when people highly appreciate ecosystem services, they more often react with some kind of action towards perceived disservices to reduce them, even at the cost of smaller provision of ecosystem service (Blanco et al., 2019). Therefore, there is an argumentation among authors that sometimes actions towards reducing ecosystem disservices could be more beneficial to people than the actions aimed towards enhanced provision of ecosystem services (Blanco et al., 2019; Lyytimäki, 2017). In that sense local knowledge could be beneficial in assessments of ecosystem disservices, hence this knowledge should be systematically collected and synthesised using multiple public participation research methods (Lyytimäki, 2017). Naturally, up until now, more research in the field of ecosystem disservices employed qualitative methods because of issues mentioned earlier, but the quantification of disservices and assessment of synergies and trade-offs among ecosystem services and ecosystem disservices and between categories of ecosystem disservices could possibly lead to the implementation of the concept into planning, management and at last into governance (Blanco et al., 2019; von Döhren and Haase, 2015). Also, since the perception of disservices is highly influenced by personal values and cultural context, participatory methods are encouraged (Lyytimäki and Sipilä, 2009).

Assessment of ecosystem disservices is a complex task, not only because of discussed methodological issues arising from a relatively young concept and understudied topic, but also because disservices are interrelated with services and their manifestation can vary in time and space (Lyytimäki, 2017; Roman et al., 2021; Shackleton et al., 2016).

Alike ecosystem services when ecosystem disservices are produced and experienced in urban areas, they are called urban ecosystem disservices (von Döhren and Haase, 2015). In urban green areas, urban trees could be seen as holders and producers of ecosystem disservices (Lyytimäki, 2017; Roman et al., 2021). Manifestation of ecosystem disservices in such complex systems is usually reflected in the form of management costs, therefore some authors even put those costs as disservices (Roy et al., 2012; Shackleton et al., 2016). Other studies state that costs are not disservices *per se*, but rather that they are one of negative consequences of disservices (Roman et al., 2021). Usually, disservices emerge from mismanagement of trees and urban green spaces, producing more costs than needed (Roman et al., 2021). Sometimes, even when people perceive disservices produced by urban trees such as damages to infrastructure, they attribute these problems to a lack of management or to bad decision-making related to management, rather than to urban trees as such (Camacho-Cervantes et al., 2014).

Management practices should account for users' perceptions while managing services and disservices (Vaz et al., 2017). Spatial mapping of disservices has been found in scientific literature, even though to a lesser extent than when it comes to services. Since disservices also emerge from people's perception, concepts of services and disservices are sometimes employed together in a mapping exercise to assess potential synergies or trade-offs among perception in relation to different types of (urban) green spaces (Baumeister et al., 2022; Ives et al., 2017; Plieninger et al., 2013; Rall et al., 2017). Spatial patterns of disservices resulted from these studies show distinctive clustering patterns indicating that locations where disservices are highly perceived can be identify in a landscape, city or urban forest.

Ecosystem disservices are linked to the functioning of ecosystems, that is species in those ecosystems, which are perceived as negative or harmful for any aspect of human well-being, i.e., allergies to pollen or animals as disease vectors (von Döhren and Haase, 2015). However, sometimes negative perceptions such as fear or discomfort in urban green spaces are not products of ecosystems' functioning, but rather their origin lies somewhere else, and as such they cannot be counted as ecosystem disservices. Regardless, negative perception is real and true for a specific place, therefore this information could be relevant for management practices employed there because it is direct user experience (Lyytimäki, 2017). If dense or unmaintained vegetation is the cause of fear in urban green space then it can be seen as an ecosystem disservice, because the origin is in the ecosystem itself, and therefore some classifications acknowledge that (Lyytimäki et al., 2008; Roy et al., 2012; Vaz et al., 2017). Conversely, when exploring fear in urban green spaces, research has shown that vegetation can highly influence, along with other variables, the amount of fear people feel while using specific places (Sreetheran and Konijnendijk van den Bosch, 2014). A recent study on disservices in urban forests discovered that the existing ecosystem disservice typologies are not of high importance for forests' visitors, but rather that the respondents have more often perceived negativities produced by other users (Baumeister et al., 2022). Other findings in scientific literature also acknowledge that disservices as perceived by people are usually not the same as proposed in classification and are often connected with other users and their behaviour or influence on the research area (Plieninger et al., 2013).

Some authors state that with assessing and clearly communicating ecosystem disservices, overly positive picture of nature produced by diverse media could be altered to a more real one (Lyytimäki, 2017). Also, in the context of urban ecosystems, there are currently many planting programs and initiatives with the aim of reducing harmful consequences of climate change that

are trying to support sustainable development of cities. However, they do not take into consideration potential disservices, costs or negative consequences that can emerge from such actions (Roman et al., 2021). Therefore, it is important to combine and complement ecosystem services and disservices firstly in research, then in practice, leading to a better-informed decision-making for multifunctional and high-quality urban green spaces.

1.2.1. Ecosystem disservices research in Croatia

In Croatia, research on ecosystem disservices produced and/or experienced in urban areas is not present in a way that utilises any of the known definitions or classifications. However, there are studies produced dealing with the dissatisfaction with certain aspects of green spaces and management employed to them. These dissatisfactions cannot be perceived as research on ecosystem disservices, but they do pose a solid background on which one can conduct further and more detailed studies, consequently leading to research of ecosystem disservices. The first such research was employed in Zagreb, among six other cities in southeast Europe, and combined positive and negative perception towards urban green spaces (Krajter Ostoić et al., 2017). Research used survey questionnaire as data collection method. Regarding negative perception, participants got a set of statements of different predefined issues that could be perceived as negative in urban green spaces to which respondents expressed their level of agreement. Also, respondents afterwards could have added their own issues if there were any. For Zagreb, vandalism was the most often expressed issue among the respondents, followed by the lack of equipment and infrastructure (waste bins and bicycle paths), presence of litter, behaviour of other users and lack of benches. Although there were more issues proposed by researchers, they received less agreement, including an issue of tree species selection (Krajter Ostoić et al., 2017). Since the research included several cities, researchers also compared the cities and observed differences, confirming the importance of local context for negative perception towards urban green spaces. Research further examined the influence of socio-economic variables on perception and concluded that these variables can explain results, but only to a small extent. It is important to mention that this research is among the first in this spatial scope to cover the topic of dissatisfaction with some aspects of urban green spaces.

On a smaller spatial scale, research conducted in Grmoščica forest in Zagreb included users' use, perception and needs towards that specific park forest (Kičić et al., 2020). The research was conducted using an on-site questionnaire as data collection method. Again, the concept of

ecosystem disservices was not discussed or employed, but rather the respondents could have expressed problems they perceive in a forest through an open-ended question, and these answers were analysed afterward. Mentioned problems were related mostly to waste (illegal waste disposal), neglect, and lack of equipment and infrastructure (benches, tables, waste bins, maintained paths); other problems have also been addressed by the respondents, but to a smaller extent (Kičić et al., 2020). Similar issues emerged as a result in both papers, despite using different types of questions to explore negative perception. The majority of issues cannot be classified as ecosystem disservices, except the tree species selection which could possibly lead to high allergic potential for some users. While the research in Grmoščica forest is spatially confined to an area of one park forest in Zagreb, the first research is more general in its nature. While this kind of research is needed and collects valid information that could further be used for informed decision-making, the spatial component is missing. That is, usually researchers do not know the exact location of the green space or to where inside the green space the respondent is referring to. With regard to proposed utilization of participatory approach in scientific literature, along with benefiting on local knowledge and the need to spatially define manifestation of disservices and the negative perception people hold towards green spaces, there is a demand for more research in this respect, not only in Croatia, but in general (Baumeister et al., 2022).

Continuing on the existing research in the field of ecosystem disservices and different aspects of negative perception people hold towards UGI, there is a call for exploring further mentioned topics of disservices, especially in the spatial and the cultural context of the city of Zagreb, Croatia. Furthermore, since research on the spatial distribution of ecosystem disservices is still scarce new information is needed to enhance the approach and our understanding of ecosystem disservices from UGI further.

1.3. Public participation GIS (PPGIS)

Public participation Geographic Information System (PPGIS) is a "*field within geographic information science that focuses on ways the public uses various forms of geospatial technologies to participate in public process, such as mapping and decision making*" (Tulloch, 2008). According to Brown et al. (2012), the term PPGIS originates from the meeting of the National Centre for Geographic Information and Analysis (NCGIA) where it was described as a process of using GIS technologies to produce local knowledge. This is especially beneficial

for cultural ecosystem service research (Brown and Fagerholm, 2015). Local knowledge is oftentimes overlooked when using proxies for quantification of ecosystem services, while the knowledge that people hold including their perception and experiences of certain locations could have a significant importance in planning and management processes (Brown et al., 2012). Especially since there exists a differentiation between experts' and users' perception of cultural ecosystem services (Riechers et al., 2017).

Scientific literature and practice differentiate among three distinguished terms and associated processes for producing spatial data primary by nonexperts: PPGIS (public participation GIS), PGIS (participation GIS) and VGI (volunteered geographic information) (Brown and Fagerholm, 2015; Brown and Kyttä, 2014; Brown and Pullar, 2012). The core of all three processes is producing spatial knowledge, but they differ in the utilisation of collected data (Brown and Kyttä, 2014). PPGIS is used for producing spatial knowledge, primarily from nonexperts, for scientific purposes or to inform spatial planning and management and to create participation opportunities for the public, especially in urban areas (ibid.). In practice, there are two ground approaches to the implementation of PPGIS studies, these include a paper map with different methods for spatial data creation, whether adhesive marker dots or pens of specific colours, and computer- or Internet-based mapping where respondents can do the mapping exercise (creating spatial data) on a digital map with digital annotation tools (Ives et al., 2017; Rall et al., 2017). PGIS is a process often employed by non-governmental organizations or used in developing countries to stimulate implementation of participation in those countries (Fagerholm et al., 2012). VGI is a process similar to PPGIS because it involves individuals creating spatial data of important locations, but they differ in a way that VGI does not have an explicit purpose rather than participants' enjoyment in the process (Brown and Pullar, 2012).

Based on a definition given by Brown and Pullar (2012) "*PPGIS attribute is any characteristic, social or physical, that can be described as having spatial extent that is requested to be identified spatially in a PPGIS*". Attributes for mapping can be diverse based on the goal of the study. However, when employed for informing urban planning, attributes are usually related to the perception of the places, activities, practices, or preferences for future land use (Rall et al., 2019). Based on a review by Brown and Kytta (2014), large diversity of participatory mapping design options emerged from a large number of possible mapping attributes (what is mapped?), different sampling approaches (who does the mapping?), the main

aim of the mapping (the reason for mapping?), technologies used (how is mapping done?) and the study area (where is mapping done?).

PPGIS questionnaires are characterised with two distinctive parts. That is, mapping part where participants mark locations on a map and questionnaire part where participants answer the classical survey questions about themselves or the mapped locations. PPGIS questionnaires are cognitively challenging for respondents who are instructed to mark places on a map which hold a distinctive attribute or meaning for them (Czepkiewicz et al., 2018). Therefore, it is important to decide upfront on a type of geometry the respondents will use to mark a place on a map. Common geometries in GIS are point, line and polygon, hence the same geometries can be used in a PPGIS research. Studies have tested additional spatial data entry geometries such as marker tool (Ramírez Aranda et al., 2021), or spray can tool (Huck et al., 2014), discussing potential benefits of the tested geometries and their usability with regard to PPGIS studies. Nevertheless, to this day the most important and widely used geometries employed within PPGIS studies remain points and lines. Points are preferred and are predominantly used as data entry geometry since they are easy to utilise in mapping exercises. Points have more reliable geometry and can simulate the spatial distribution of perception on a map with satisfying accuracy. Diversity of research has successfully employed points as a spatial data entry method at different spatial scales (Baumeister et al., 2020; Fagerholm et al., 2016; Jaligot et al., 2019; Korpilo et al., 2021; Rall et al., 2017).

Some of the determinants of collected data quality using PPGIS questionnaires are the type of attribute to be marked, the quality of the environment in which mapping will be taking place as well as the respondent's map literacy (Brown and Pullar, 2012). Research shows that spatial data collected with PPGIS questionnaires are reasonably accurate. The respondents from studies employed in New Zealand have had an average error rate of about 6% when mapping the locations with native vegetation, therefore the reliability of PPGIS as a tool for collecting spatial data has been empirically demonstrated (Brown, 2012). Another important result of the aforementioned study is the smallest error rate found among people who volunteered to be a part of the research emphasising a willingness to participate as an important factor describing and influencing the accuracy of the placed spatial markers in PPGIS questionnaire.

Usually, when the study uses Internet PPGIS applications there are two possibilities: to use one of the commercial applications such as Maptionnaire (Baumeister et al., 2020; Fagerholm et al., 2019; Jaligot et al., 2019; Rall et al., 2017) or to develop one's own application for use

within the research (Garcia et al., 2020; Korpilo et al., 2018; Ridding et al., 2018). This proves the versatility of options provided by using the PPGIS questionnaire as data collection method.

1.3.1. PPGIS as an added value to assessment of cultural ecosystem services and disservices

Spatial component is emphasised in the participatory mapping process where respondents are asked to designate locations with specific characteristics on a map. When participatory mapping is combined with the concept of ecosystem services, then characteristics of space that the respondents are asked to identify on a map are associated with provision of direct and indirect services by ecosystems which are of relative importance to respondents and their well-being (Brown and Fagerholm, 2015). Since cultural ecosystem services are intangible in nature, mapping of their perception and therefore provision enables the conversion of perception into a quantitative form which can be analysed using various spatial and statistical methods (Jaligot et al., 2019; Ridding et al., 2018). Likewise, maps are a powerful tool when communicating the spatial extent of the phenomena explored. Mapping of cultural ecosystem services and disservices thus enables producing maps of hotspots and coldspots of their provision, while allowing easier communication of results between researchers, experts and the interested public respectfully (Baumeister et al., 2020; Korpilo et al., 2018; Rall et al., 2017). Translating cultural ecosystem services' and disservices' perception into maps could therefore be of a great benefit to decision makers and experts in diversity of fields to enhance their practice and incorporate users' perception and use in their work.

When employing the PPGIS questionnaire as data collection method for mapping cultural ecosystem services and exploring their distribution, spatial location is the most important information gathered (Brown and Fagerholm, 2015). However, nearly always when conducting a PPGIS study, alongside spatial data, data on socio-demographic characteristics of respondents and additional data are collected. This information allow for complete comprehension of the sample and for in-depth analysis of spatial data in relation to different respondent's characteristics. Additional data collected with PPGIS questionnaire are not confined to socio-demographics, rather to all relevant information that is deemed necessary to completely understand phenomena under investigation.

Research on more than 200 applications of the PPGIS tool in the planning process concluded that the PPGIS is versatile enough to be applied in a multitude of spatial scales and for a multitude of planning demands (Kahila-Tani et al., 2019).

1.4. Study area – City of Zagreb – spatial and cultural context

Study area chosen for this research is the city of Zagreb. Zagreb is the capital of the Republic of Croatia, and it is its administrative and political centre alongside being the biggest and most populated city. It is located in northwest part of Croatia at 45º49' N longitude and 15º59' E latitude (Figure 1) and covers the area of 641.24 km^2 (SYCZ, 2021).

Based on data from Statistical Yearbook of the City of Zagreb (SYCZ) published by the City Office for Strategic Planning and Development of the City of Zagreb, the population of Zagreb is 809,268 citizens (estimated for 2020) out of which 426,931 females and 382,332 males. Age-wise the largest number of citizens is in the age group 35-39 years, while the smallest number of citizens is in the age group of 85+. The average citizen of Zagreb is 41.6 years old. More than half of the citizens are employed and approximately for the same share of citizens the highest achieved level of education is high school.

Regarding UGI, there is a diversity of different green spaces present in the city of Zagreb. Roughly, the same amount of area is allocated to built-up area, forested area, and agricultural area. Management of parks, tree lines and neighbourhood greenery in the city of Zagreb is assigned to a city-owned company (Zrinjevac), while state-owned forest management company (Croatian Forests Ltd.) is assigned to manage all forests and park forests except the private ones on behalf of the city of Zagreb (Krajter Ostoić, 2013). Listed hereafter are presented the most important parts and locations of UGI in Zagreb (photographs of some are presented in Figure 2).

Medvednica Mountain on the north of the city is one of the most important specificities of the city of Zagreb. Medvednica is a large, forested area that has been a nature park since 1981. Out of the whole Park's area of 17,938 ha around 8,500 ha is located in the city of Zagreb. The highest point is the peak Sljeme (1,035 m a.s.l.) which also represents the highest point in the city of Zagreb. Forest cover is a distinguishable trait of Medvednica with 12 different forest association being present in the area. Management of Nature Park is under the jurisdiction of the Public Institution founded by Ministry of Economy and Sustainable Development of the Republic of Croatia. Except biodiversity hotspot, Medvednica is popular hiking destination for

citizens of Zagreb and tourists alike with around seventy hiking trails throughout the mountain (URL1).

Park forests in the city of Zagreb are natural extension of the forests of Medvednica Mountain descending into the urban landscape of the city. They extend approximately 20 km in the direction west – east and around 9 km in the direction north – south. These forests are characterised by being smaller, disconnected and intersected with urban landscape. Emphasised recreational, aesthetical, and ecological functions provided by forest parks also dictate their management and are distinguishing traits between them and other forests in the city of Zagreb. These forests have great natural-scientific, ecological, social, and commercial value and because of that, they are still preserved. Less than 50% of these forests are privately owned, while the rest is state-owned (Matić, 2010). Privately owned forests are under the management and responsibility of their owners, while Croatian Forests Ltd., Forest Administration Zagreb, Operational Unit Urban Forestry manages state owned forests on behalf of the city of Zagreb. The city of Zagreb takes care of the maintenance of these forests based on annual financial plans, while the long-term planning and management is based on the Forest Management Plan (2014 – 2023) made by Croatian Forests Ltd. for all park forests as one management unit (both privately and state-owned) (Krajter Ostoić, 2013).

Maksimir Park is the biggest and the most important park in Croatia. As such it is one of the symbols of Zagreb while at the same time being the most important work of landscape architecture (Bojanić Obad Šćitaroci and Obad Šćitaroci, 2004). It has an area of around 400 ha which was and still is a rather large area dedicated for a public park. Its' significance also lays in being the first public park in Southeast Europe established in 1794 with the purpose, among others, to serve local citizens as place for rest and relaxation (ibid.). Even though the design of the Maksimir Park changed with time, the most important features like oak forest on the north, landscaped elements on the south and water features remained. Its' primary goal also remained the same and today Maksimir is open to citizens and tourists alike in search of nature in the city of Zagreb. Because of its historical importance Maksimir has been protected as the monument of park architecture by the Ministry of Economy and Sustainable Development. The Maksimir Public Institution for the Management of Protected Areas of the City of Zagreb is responsible for management of Maksimir Park, along with other protected areas in the city of Zagreb.

The second historically important part of UGI in Zagreb is the green system known as The Green Horseshoe or Lenuci's Horseshoe. The Green Horseshoe is the name for seven square parks and the botanical garden that encircles the Zagreb's city centre from three sides forming a U-shape. These square parks to this day serve as squares and parks alike. The Green Horseshoe consists of Nikola Šubić Zrinski (Zrinjevac) Square, Josip Juraj Strossmayer Square, King Tomislav Square, Ante Starčević Square, Botanical Garden, Marko Marulić Square, Mažuranić Square and the Republic of Croatia Square. These locations were designed by Milan Lenuci, hence the name, by the end of 19th century. They are representative for the city and largely influence urban identity of the city of Zagreb (Bojanić Obad Šćitaroci and Obad Šćitaroci, 2004).

Parks Jarun and Bundek are somewhat younger and were established in 1987 (Jarun) and 2006 (Bundek). Jarun was developed for the purpose of XIV Universiade held in Zagreb in 1987. Jarun covers the area of 240 ha out of which 30% is water. It has two lakes and six islands along with high biodiversity and a multitude of recreational infrastructure (water and land sports alike). It is one of the most popular outdoor areas in the city of Zagreb (URL2). Bundek Park is spatially connected with river Sava in being in its close proximity. It originated as an artificial lake as a result of material excavation, and was later developed into a park in 2006. It has an area of 54.5 ha out of which 47 ha is green areas, 5 ha water areas and 1 ha walking trails. Just like Jarun, it has two lakes and a highly developed visitor infrastructure (URL3).

Sava River is the last large element of green infrastructure in the city of Zagreb. 28 km of the river pass through the city borders. It has historical importance in the development of the city of Zagreb. Also, Sava River is the natural border between Old Zagreb (north) and New Zagreb (south) (Vujasinović, 2007). Today along the Sava River there are embankments, used by citizens of Zagreb for multitude of purposes.

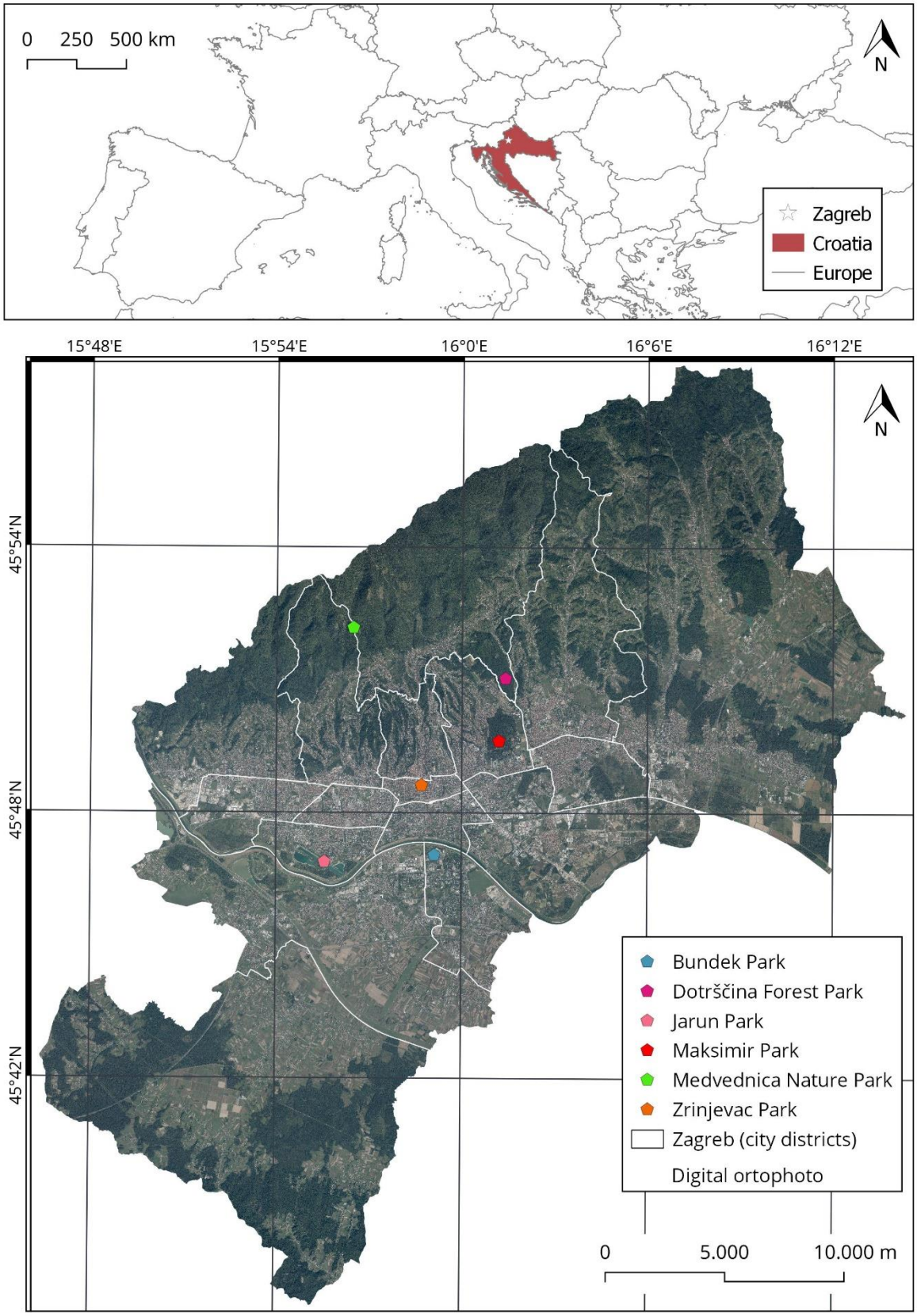


Figure 1 Map illustrating the position of Croatia and Zagreb in Europe (top) and map of the City of Zagreb with city district boundaries (bottom) – base map is a digital orthophoto obtained from Croatian Geodetic Administration, while the city district boundaries were extracted from Land Use dataset obtained from the City of Zagreb

Figure 2 Picture collage showing diversity of UGI in the city of Zagreb - a) park Maksimir, b) slopes of Medvednica mountain, c) Nikola Šubić Zrinski (Zrinjevac) Square, d) Dotrščina Forest Park, e) Jarun Park, f) Bundek Park, g) a forest, h) water feature

Administratively, Zagreb is divided into 17 city districts and 218 community boards respectively (see Figure 1 for distribution of city districts). Together, they represent a form of local self-government that decides on local issues together with citizens whose everyday life is directly affected by them. Therefore, it represents a way of co-governance in the city on a smaller spatial scale. Yet, co-governance and participation are not utilised to reach their full potential. For example, earlier research based on an in-depth interview with stakeholders in Zagreb has shown that when it comes to management of urban forests as a part of green infrastructure, public participation and involvement emerges as a matter that needs improvement (Krajter Ostoić, 2013). Also, in general, when it comes to spatial planning and related changes of most often public spaces, public participation in Zagreb is lacking or it is strictly formal, therefore public does not have much influence on decision-making (Sviršić Gotovac et al., 2021). The same paper also stresses different possibilities that the city government can use to exclude public opinion in the last phases of the project, which sometimes leads to strong negative public reaction also called reactionist activism. That negative public reaction is usually manifested through organized protests against made decisions where experts and laypeople alike engage in demonstration of their discontent. The most well-known examples of negative reaction in Zagreb are related to Savica Park and the associated campaign “Save Our Park” and also the negative reaction to the renovation of Meštrović Pavilion with campaign “Bring Back the Magnolia Tree” (Sviršić Gotovac et al., 2021). These examples emphasise the need for consideration of public opinion in decision-making in the city of Zagreb.

Furthermore, with public involvement into decision-making process there is an argument that the process that is well-designed and appropriately conducted could be beneficial to decision-making and lead to better and widely accepted decisions (Reed, 2008).

2. HYPOTHESES AND OBJECTIVES

Based on the findings reported in the scientific literature along with the current knowledge about the perception and use of cultural ecosystem services and disservices in the city of Zagreb two hypotheses have been proposed for this work.

H1: Cultural ecosystem services and disservices of urban green infrastructure are not randomly distributed across urban landscape, yet their provision is characterised by the type of urban green infrastructure.

H2: Perception and use of cultural ecosystem services and disservices depends on socio-demographic characteristics of respondents, type of urban green infrastructure, general habits of urban green infrastructure use, distance from home and urban-rural gradient.

Proposed objectives for this thesis are as follow:

O1: To map and analyse cultural ecosystem services and disservices' distribution across different types of urban green infrastructure at the city scale.

O2: To explore different factors influencing the perception and use of cultural ecosystem services regarding different types of urban green infrastructure at the city scale.

O3: To identify those factors that primarily determine the quality of cultural ecosystem services and use of urban green infrastructure in the city of Zagreb.

3. MATERIAL AND METHODS

3.1. Research design

Methodology employed for this research is conducting a PPGIS questionnaire on a sample of population in the city of Zagreb. Perception of cultural ecosystem services and disservices of UGI (or urban green space) is proven to be highly subjective and spatially explicit while at the same time the PPGIS questionnaire is a proven and useful method for the assessment of such services (Brown and Fagerholm, 2015).

Methodological approach used for this study was to conduct an exploratory, quantitative, participative, and cross-sectional study. Since the qualitative data on the perception of cultural ecosystem services in the city of Zagreb is gathered beforehand (Krajter Ostoić et al., 2020a), the aim of this study is to utilize those findings and quantify them. Exploratory approach is suitable because this is the first large-scale operationalization of PPGIS questionnaire in the study area and the results could be further used to refine and enhance spatially-explicit approaches in the future (Brown et al., 2015b). Quantification of perception is needed to better understand the relationship and value people assign to cultural ecosystem services and disservices that could lead to monetizing these services and subsequently including them into decision-making (Haase et al., 2014). Also, qualitative and quantitative methods employed together are a preferable approach to understanding completely the concept of cultural ecosystem services (Hegetschweiler et al., 2017).

The defined sample of population includes residents of the city of Zagreb being 18 years old and older. The sample consisted of those residents who are old enough to vote and participate in public life. Sufficient (target) number of respondents was calculated based on the total number of citizens in the city of Zagreb (809,268) with confidence level of 95% using sample size equation. Also, the sample defined in previous research conducted in the study area was used as guidance (Krajter Ostoić et al., 2017). Therefore, target number of respondents for this study was defined to be 384, which is also in accordance with sample size defined for the previously mentioned study. Area of interest (AOI) for this research is defined to be the entire city of Zagreb while the specific spatial focus is put on different types of UGI throughout the city.

Because the research includes human subjects, prior to the employing the questionnaire and conducting the research, research design, as well as the defined questionnaire, got approval

from the Ethics Committee of the Faculty of Forestry and Wood Technology, University of Zagreb with the reference number EP01-21/22.

It was decided upfront that research will be conducted online and that the respondents will be filling in the questionnaire without the help of a facilitator. Online approach to conducting the PPGIS questionnaire was chosen since spatial extent of the study area is rather large, as is the targeted population. The utilization of a PPGIS questionnaire is a novelty for the study area where high participation tried to be achieved. Studies addressed usefulness of online approach in enhancing participation in PPGIS research (Rzeszewski and Kotus, 2019). Further, online distribution of a PPGIS questionnaire is usually employed within exploratory studies on large spatial areas because it is believed that with this approach target and representative sample could be gathered (Beckmann-Wübbelt et al., 2021; Jaligot et al., 2019; Rall et al., 2017). Moreover, it is easier to conduct an online survey in relation to a paper survey and it is also a less expensive approach with the presumption that technological literacy of citizens of Zagreb is sufficient for the utilization of this approach. Even though some previous research used a facilitator to facilitate participation, they also used a stratified sample of participants (Fagerholm et al., 2016). Within this study the combination of convenience and targeted sampling was used as in studies with similar aims and spatial extent (Jaligot et al., 2019; Rall et al., 2019). PPGIS questionnaire was designed and uploaded onto a webpage with a customized URL. The questionnaire was active from 18th June until 11th November 2021; therefore, data collecting phase lasted for four months and 25 days.

During the data collection period, different ways of distributing the questionnaire and reaching to the target population were used. Throughout the whole data gathering period, the dynamics of data collection and spatial distribution of respondents who participated was supervised. That allowed for refining the campaign efforts to stimulate those parts of the city where smaller number of respondents were engaged. After the data collection period has ended, data analysis was performed to produce results, test the proposed hypotheses and to bring conclusions.

This research is part of the science project “Improving green infrastructure planning and management through participatory mapping of cultural ecosystem services (CULTUR-ES)” funded by Croatian Science Foundation under the grant number UIP-2017-05-1986 conducted at the Croatian Forest Research Institute.

More about the process of designing the questionnaire, data collection and analysing the data is described hereafter.

3.2. Questionnaire design

Influenced by proposed hypothesis and objectives, *MyDynamicCity* Zagreb, a PPGIS questionnaire used in this research, was designed with the dual aim. The first aim was to collect the spatial data to explore and quantify spatial distribution of perception towards selected cultural ecosystem services and disservices provided by UGI in the city of Zagreb. The second aim of the questionnaire was to collect the data to explore if specific socio-demographic or visiting behaviour of the respondents' influence revealed spatial perceptions. Overview of the concepts tested, discussed, and employed within this research and PPGIS along with their interrelation with hypotheses is presented in Table 1.

Main characteristic of a PPGIS questionnaire is that it combines the spatially explicit approach implemented through mapping exercises with classical questionnaire technique to explore a topic of interest on a sample of population. Commonly, the design of a PPGIS questionnaire consists of defining questions and applying methods for collecting spatial data about the phenomenon of interest alongside deciding and defining additional questions for non-spatial variables one wants to explore in relation to spatial data. When deciding on spatial data gathering approach it is of great importance to choose appropriately the geographic entity (point, line, or polygon) which the respondents will use to mark a specific place on the map (Ramirez Aranda et al., 2021). This decision will influence the quality of spatial data collected with the questionnaire (Brown and Fagerholm, 2015).

Accordingly, two distinct parts of the questionnaire are designed. The first part of the questionnaire consists of questions about respondents' relevant socio-demographic information alongside the data about their usual behaviour related to visiting green spaces in Zagreb, while the second part of the questionnaire was designated for mapping distinct cultural ecosystem services' and disservices' spatial attributes on a digital map of Zagreb.

Table 1 Interrelation between main concepts, variables and hypotheses tested in research of the perception of cultural ecosystem services and disservices in the city of Zagreb

Concept	Variable	Variable type	Collected	Hypothesis	
				H1	H2
Urban green infrastructure	UGI classification	GIS vector layer (polygon)	Produced **as secondary vector dataset** from two separate official vector datasets	Cultural ecosystem services and disservices are not randomly distributed across urban landscape, yet their provision is characterised by the type of urban green infrastructure.	Perception and use of cultural ecosystem services and disservices depends on socio-demographic characteristics of respondents, type of urban green infrastructure, general habits of urban green infrastructure use, distance from home and urban-rural gradient.
Cultural ecosystem services	Place of residence	GIS vector layer (point)	Collected with MyDynamicCity Zagreb PPGIS questionnaire **mapping questions**		
	Place attachment	GIS vector layer (point)			
	Recreational use (attributes)	GIS vector layer (point)			
	Aesthetics (attributes)	GIS vector layer (point)			
	Education	GIS vector layer (point)			
	Cultural Identity	GIS vector layer (point)			
Ecosystem disservices	Disservices (attributes)	GIS vector layer (point)	Collected with MyDynamicCity Zagreb PPGIS questionnaire **mapping questions**		
Public participation	Socio-demographic	Categorical data	Collected with MyDynamicCity Zagreb PPGIS questionnaire **open-** and **closed-ended questions**		
	Visiting behaviour	Categorical data			

Spatial attributes of cultural ecosystem services and disservices used for mapping in a PPGIS questionnaire are chosen based on prior conducted research on the topic of cultural ecosystem services' perception and use by the inhabitants of Zagreb's city districts. Research employed focus group methodology and residents of all Zagreb's city districts were included. This research resulted with the data on the most abundant and the most important attributes of perception people hold towards cultural ecosystem services provided by urban green spaces in Zagreb (Krajter Ostoić et al., 2020a). A recommendation mentioned is that before designing and conducting a PPGIS questionnaire whose aim is to quantify the perception, qualitative research employing methodologies such as focus groups or interviews should be conducted to refine the instrument, that is to design a questionnaire that will be adapted to the local context and to explore further only the most important categories employing suitable approaches towards participatory mapping (Riechers et al., 2018; Rzeszewski and Kotus, 2019).

Layout and mapping approach used for *MyDynamicCity* Zagreb PPGIS questionnaire are based on several successfully designed and employed PPGIS questionnaires on the topic of cultural ecosystem services, or their specific attributes, whose results are reported in scientific literature (Brown et al., 2015a; Fagerholm et al., 2019; Jaligot et al., 2019; Pietrzyk-Kaszyńska et al., 2017; Rall et al., 2017; Ridding et al., 2018). Since the whole city of Zagreb is the AOI for this research and specific proposed goals slightly differ from landscape contexts and goals of the majority of above-mentioned research, they are used as the current state-of-the-art in a PPGIS research. As such, they pose a good foundation to build a useful data-gathering platform, the one that is adapted to local context and research needs. Besides, there is still no specified guidance for researchers to refer to while designing and implementing participatory mapping with regard to spatial context and attributes that will produce valid results (Brown and Fagerholm, 2015; Brown and Kyttä, 2014). Therefore, researcher's task is to build a platform that will use and adapt the existing methodological approaches and knowledge to build a useful questionnaire.

If a researcher opts to use online PPGIS data gathering approach in research, as already mentioned, the one usually has two options regarding the platform employed for the aim. Two approaches include using one of the commercially available platforms or to design and develop its own application that will be used for the purpose.

For the PPGIS research employed in the city of Zagreb, *MyDynamicCity* application was developed. Web-application is based on two separate web-developments combined into one –

SilkverKNETs tool (Scheuer et al., 2018) and MyDynamicForest (Korpilo et al., 2018). The first application provided options for the configuration of non-spatial questions and gathering different non-spatial data, while the latter is used for configuring and collecting spatial data. While designing a web-application that hosted a PPGIS questionnaire, the available open-source libraries were used, such as Leaflet for interactive maps, Font Awesome for icons and OpenStreetMap as a base map. Complete control over the design, visually and structurally, of the questionnaire including layout (number of pages), contextual and mapping questions design and variable names is left for the researcher who designed the questionnaire via the XML vocabulary to decide. The PPGIS questionnaire was designed to be available in Croatian and English language, and in a way that could be used with personal computers or smartphones. All responses in the questionnaire are saved into SQLlite (sqlite3) database with upfront designed variable names and in an appropriate format. Each respondent was granted with a unique randomly generated *userid* number in a database that allowed the distinguishing between respondents, while at the same time complied with data privacy. Final structure of *MyDynamicCity* Zagreb PPGIS questionnaire is presented in Figure 3.

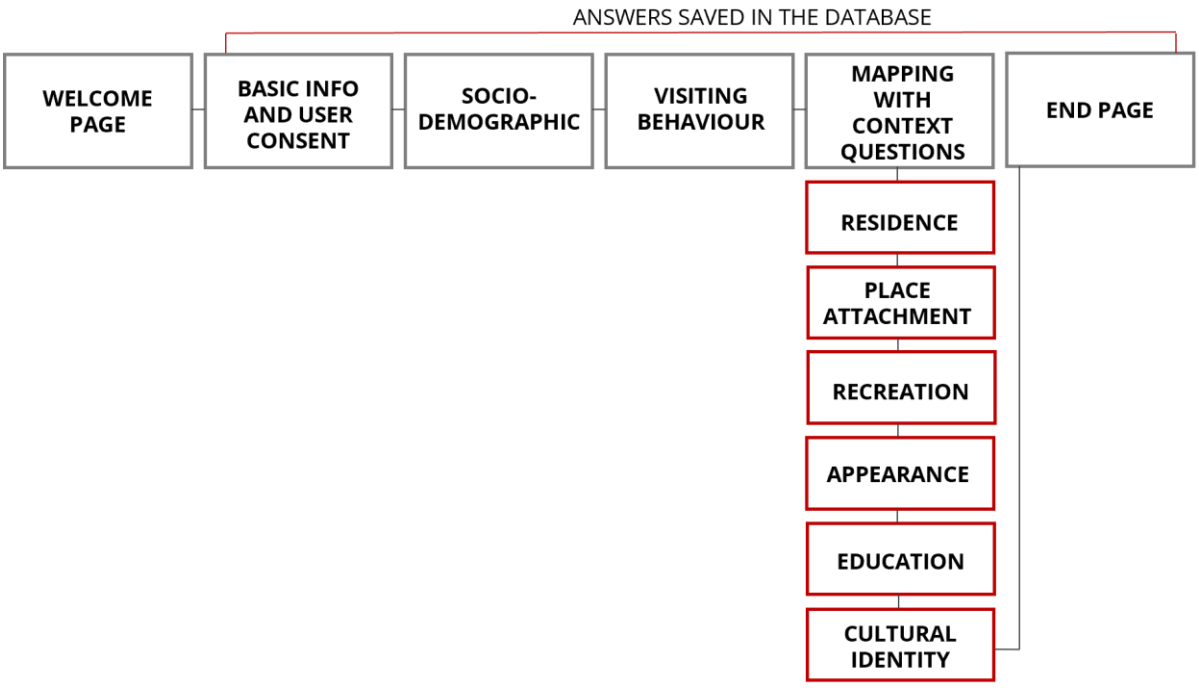


Figure 3 Internal structure of the MyDynamicCity Zagreb PPGIS questionnaire

3.3. Data

Ahead of participating in the PPGIS questionnaire and consequently in the research, all respondents were presented with the information about the aims and goals of the research, collected data policy, contacts of the researchers and had to provide their consent for being included into research.

Two types of data that were collected within this research include non-spatial and spatial data.

3.3.1. Non-spatial data in detail

Non-spatial data consists of socio-demographic information about the respondents, data on respondents' usual behaviour when visiting green spaces in Zagreb and additional non-spatial data collected to complement spatial markers placed on a digital map.

Usually, non-spatial data in PPGIS questionnaires are used to provide a context for the collected spatial markers and to assess representativeness of the collected sample of population. Since PPGIS questionnaire as data collection method relies on the respondents' involvement, these types of questions are necessary for data analysis and the interpretation process conducted later. In *MyDynamicCity* Zagreb PPGIS questionnaire a combination of open- and closed-ended questions was employed when collecting non-spatial data, where closed-ended questions included Likert scales, and multiple-choice questions.

Socio-demographic variables include data about respondent's gender, age, highest achieved level of education, employment status, household income, number of people in a household, number of underage children in a household and having a dog in a household.

Gender, highest achieved level of education, employment status, household income and having a dog were explored using closed-ended questions where respondents could choose one from the pre-defined answers. These variables were collected and treated as categorical data.

Data on age, number of people in a household and number of underage children in a household was collected in a form of open-ended questions. The respondents were asked to write in a number indicating their age, the number of people living in the household and the number of underage children living in a household. These variables were collected and treated as numerical. However, data on age was later transformed to categorical variable by grouping into age groups and further used as such.

Questions about respondent's behaviour while visiting green spaces are contextual i.e., can be used to broaden the knowledge about the sample of respondents and the people who took part in the questionnaire. Questions on visiting habits included information on city district respondent is living in, how long respondent is living in its respective city district, how long respondent is living in the city of Zagreb, frequency of visits to urban green spaces in Zagreb, usual mode of transportation to urban green spaces in Zagreb, part of the day in which respondent usually visits urban green spaces, part of the week in which respondent usually visits urban green spaces, length of staying in urban green spaces, with whom respondent is visiting urban green spaces and did respondent change visiting frequency to urban green spaces because of the COVID-19 pandemic.

Data on city district respondent is living in, frequency of visits to urban green spaces in Zagreb, mode of transportation, data on part of the day and part of the week respondent is visiting urban green spaces in Zagreb, length of staying, with whom respondent usually visits urban green spaces in Zagreb and data related to COVID-19 was collected using closed-ended questions where respondents could choose one from the pre-defined answers. These data are categorical and treated as such in data analysis.

Data on the length of living in the city district and in the city of Zagreb was collected in a form of open-ended questions where respondents were instructed to write in a number representing the number of years as an answer to each question. These data was collected and treated as numerical.

Third category of non-spatial data are complementary data to placed spatial markers on the map in the process of mapping. Complementary data included the information on perceived quality of marked places, perceived access to those locations, personal importance placed on the provision of specific cultural ecosystem services and disservices and specific traits of marked placed that emerged as an important during focus group interviews. Respondents could rank perceived quality and accessibility on a 7-point slider, while personal importance was expressed on a 5-point Likert scale with 1 being not at all important and 5 represented of uttermost importance. Respondents were also presented with traits that could be attached to the marked locations on a map which were upfront defined by the researcher alongside an instruction to mark all that apply in a form of close-ended question.

3.3.2. Spatial data in detail

Spatial data was collected by employing participatory mapping. Mapping included several categories and associated attributes of cultural ecosystem service and disservice perception. Spatial data is characterised by having a spatial component, i.e. designating a specific location on Earth described with spatial coordinates. Spatial data collected with *MyDynamicCity* PPGIS questionnaire included approximate home location of the respondent and locations of cultural ecosystem service and disservice perception.

Perception locations are gathered for Place Attachment defined as favourite green spaces, locations used for Recreation, locations of perceived positive (Aesthetics) and negative (Disservices) characteristics of green spaces, locations used for Educational purposes or those with educational potential and locations of perceived Cultural Identity. All spatial data except for approximate home location is related to the perception of cultural ecosystem services and disservices provided by UGI in the city of Zagreb. All mapping questions employed points as geographic entities to mark a location since this represents the easiest way for the respondents to produce spatial data and at the same time they are the preferable geographical entity for respondents to use (Brown and Pullar, 2012). Further in text the term ‘spatial marker’ will be used to represent points holding different attributes which the respondents placed on a map. Spatial data was written in the database as latitude-longitude coordinates of each placed spatial marker.

Spatial data was collected using a digital map and digital markers. During the test phase of questionnaire development, test respondents tested different map options for the base map such as OpenStreetMap and satellite imagery overlaid with labels indicating streets and other important toponyms. The majority of respondents who tested the application preferred the OpenStreetMap option for base map; therefore, this option has been implemented in all mapping questions. To ensure spatial data accuracy, while filling in the questionnaire the respondents have been instructed to use zoom and be as precise as possible while mapping. The same instruction was posted alongside each mapping question. Minimal zoom required for mapping, even though implemented in some studies to ensure spatial data quality (i.e., Brown et al., 2018), was not predetermined.

Approximate home location of respondents

Due to respecting the respondents' data privacy, the questionnaire did not ask for the exact home address. However, to collect this information polygon representing a spatial grid of 500 m × 500 m was prepared beforehand in GIS and was overlaid over the base map covering the city of Zagreb. The respondents were instructed to place a digital marker indicating their home location by clicking anywhere in a square containing their home address. Clicking placed a spatial marker on a map. By doing that, the privacy of respondents was guaranteed while allowing for future data analyses. Only one marker was allowed on a map. The respondents were not obligated to mark their approximate home location to progress further with the questionnaire.

Locations of perceived cultural ecosystem service of urban green infrastructure – Place Attachment

Cultural ecosystem service's category of Place Attachment was operationalised in the questionnaire as the respondents' favourite green spaces in Zagreb. Spatial markers representing locations where the respondents perceive place attachment were collected on a digital map of the city of Zagreb. The respondents were instructed to map up to three different locations of green spaces in Zagreb that they perceive as their favourite. The mapping system used for this question was click to map, in other words, the respondents placed a spatial marker on a map by mouse clicking on the desired location (if they used personal computers) or touching the map location on a screen (if they used smartphones). After clicking, markers appeared on the map. Markers could have been removed from the map by clicking on a specific marker tag the respondent wanted to remove. The respondents were instructed to use zoom while mapping and to be as precise as possible. They did not have to put all three markers on a map; thus, they could put fewer markers (none, one or two) on the map, but not more than three because the application did not allow putting more than three markers on the map. Figure 4 shows the spatial marker placed on the map as seen by the respondent.

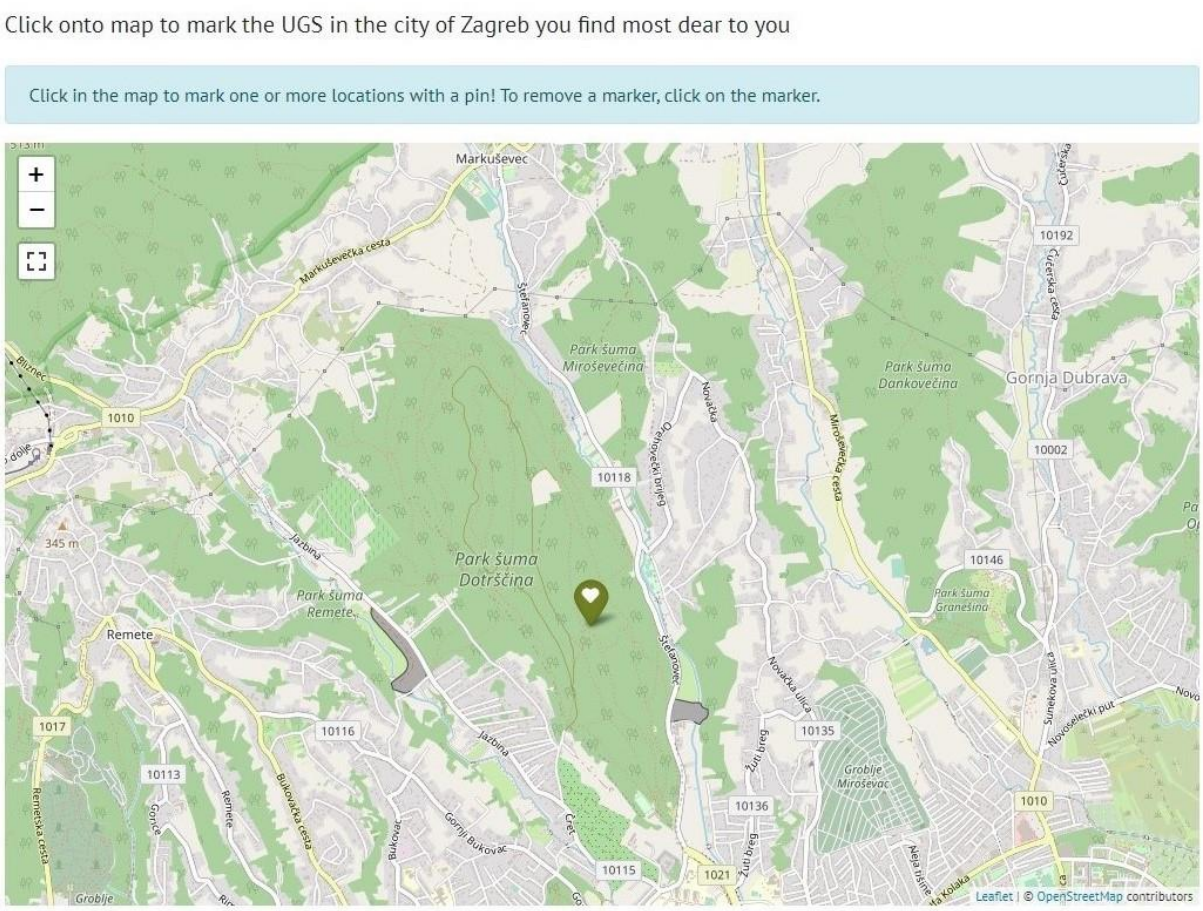


Figure 4 Spatial marker placed on the map for cultural ecosystem service of Place Attachment in the PPGIS questionnaire

Locations of perceived and used cultural ecosystem service of urban green infrastructure – Recreation

Cultural ecosystem service's category of Recreation was operationalised in a questionnaire as green spaces in the city of Zagreb that the respondents use for recreation. During focus group interviews the respondents mentioned a multitude of different recreational activities they undertake in green spaces in Zagreb (Krajter Ostoić et al., 2020a). Following those mentioned and wanting to explore whether there are differences in provision of recreational activities between different types of UGI, the respondents could choose and mark specific attributes (activities) of recreation. The respondents were instructed to place on a map at maximum three different locations up to six markers representing recreational activities they undertake there since, usually, people engage with more than one recreational activity while visiting green spaces (Vierikko et al., 2020). Also, activities people undertake in urban green spaces are not always active (Brown et al., 2018, 2014). Therefore, a pre-defined set of activities that the respondents had the possibility to map reflected the diversity of actions, including active,

passive, and social activities as well. To make sure that the results of mapping are consistent with other mapping questions, the respondents were instructed to map only three different locations in the city of Zagreb. Moreover, it is expected that the frequency of mapping certain activity attribute will show those activities that are more important to the respondents and those that are perceived or used to a lesser extent by the respondents. Mapping system utilized for this question was 'drag and drop'. Markers representing different recreational activities, i.e., attributes of recreation were upfront defined by the researcher and presented to the respondents for them to choose which one to place on the map. Recreational attributes were Walking, Running, Hiking, Watching Nature, Biking, Dog Walking, Taking the Kids Out and Socialising. Even though there are many options to map more than one attribute, 'drag and drop' presents an intuitive and easy option for the respondents to understand and use, while it is also successfully integrated in other PPGIS studies, e.g., Brown et al. (2014). 'Drag and drop' is utilized through attributes for mapping which are placed on the ribbon above the digital map and when upon deciding which one to map, the respondent dragged the chosen marker from the ribbon and dropped it on the desired location on a map.

Locations of perceived aesthetic cultural ecosystem services and disservices of urban green infrastructure – Aesthetics and Disservices (Appearance)

The mapping question related to the perception of green spaces' appearance in Zagreb combined positive and negative features that can be perceived in urban green spaces in Zagreb. To reduce the respondents' overload while taking the questionnaire and subsequently high drop-out rate, this mapping question combined attributes of cultural ecosystem service of Aesthetics and attributes of perceived Disservices. Together they formed Appearance category. Alike recreational use, appearance of one urban green space is not straightforward, but rather interconnected with positive and negative perception people hold (Baumeister et al., 2022). Aesthetics as cultural ecosystem service of UGI is explored through the following attributes: Maintained, Aesthetical Experiences (Beautiful), Naturalness, and Restorative. During focus groups conducted with citizens of Zagreb, disservices were usually mentioned in relation to maintenance, behaviour of other users, or some specific characteristics of a place; therefore, the chosen attributes of negative perception or disservices are Unmaintained, Scary, Noisy and Conflicts. The mentioned attributes of appearance were presented to the respondents to choose and mark on a map. Positive and negative attributes were also distinguished by the background colour of a marker on a ribbon to facilitate mapping. Again, the respondents were instructed to

mark up to three different locations and use a maximum of six markers using the ‘drag and drop’ option as in previous question. More than six markers were not allowed by the application ensuring control over the quantity of spatial data collected.

‘Drag and drop’ approach employed in PPGIS questionnaire in Zagreb is presented in Figure 5.

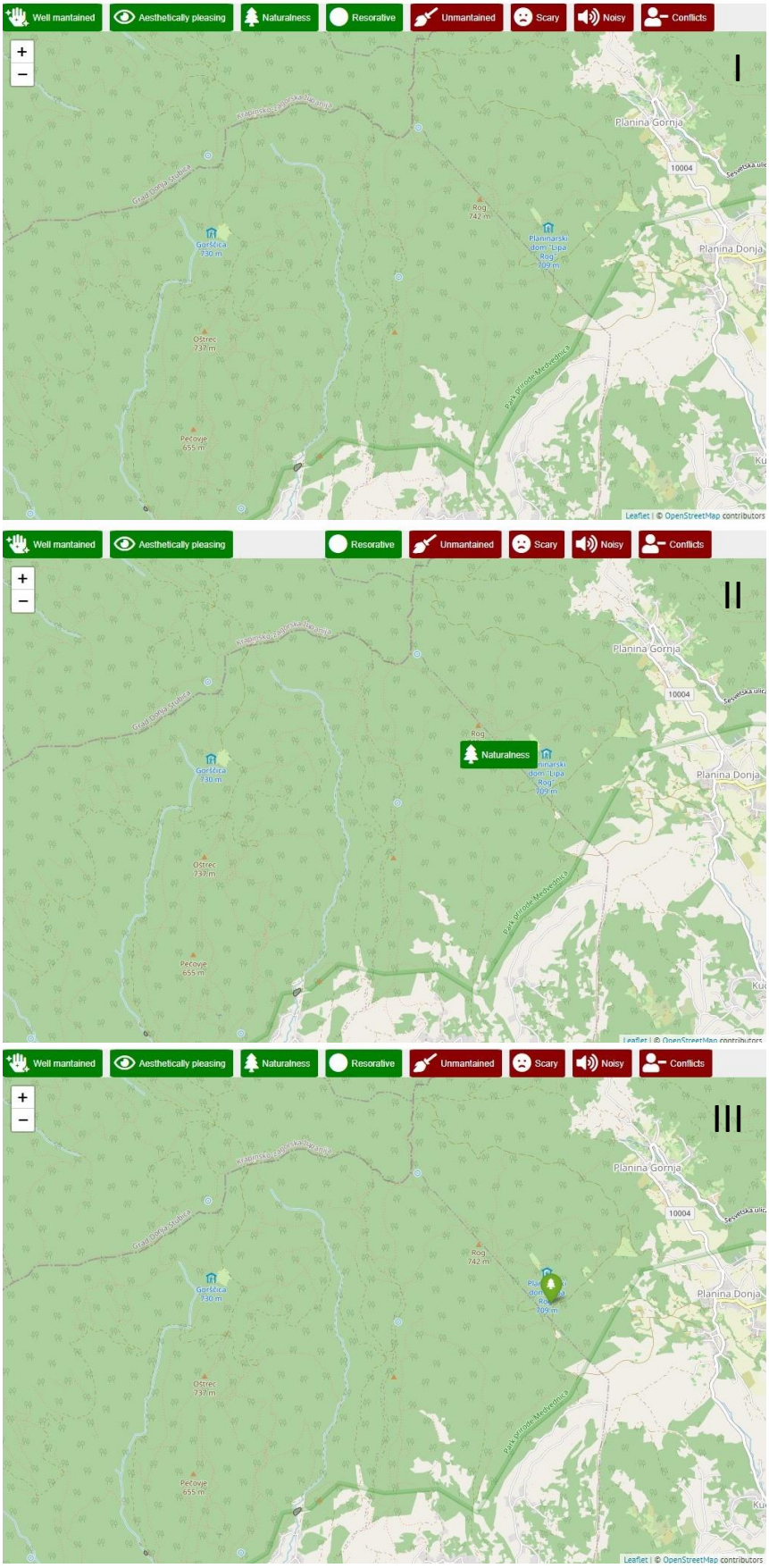


Figure 5 Mapping the desired location using drag and drop option presented in three steps I) choosing the attribute; II) dragging the attribute on the map; III) dropping the attribute on a location and marking it

Locations of perceived and used cultural ecosystem service of urban green infrastructure – Education

Education as cultural ecosystem service of UGI is mapped in a next mapping question in the following way: the respondents have been instructed to map up to three different locations of green spaces in Zagreb that are used or can be used for educational purposes. It was emphasised to the respondents that education as a cultural ecosystem service is not exclusively intended as children's education about nature, but that it is intended for all citizens of Zagreb to have the opportunity to learn about nature in urban green spaces. By clicking on the map a spatial marker appeared. Application did not allow the placing of more than three markers on the map, while less than three was allowed. The respondents have been instructed to use zoom and be as precise as possible with mapping.

Locations of perceived cultural ecosystem service of urban green infrastructure – Cultural Identity

Cultural Identity as a cultural ecosystem service of UGI was defined as green spaces in Zagreb which symbolize or can be used to identify city or city district. Those locations that hold historical importance, an interesting story, or something else that the respondents find important for the category of cultural identity as presented in the results of focus groups (Krajter Ostoić et al., 2020a). The mapping system used for this question was the same as for Place Attachment and Education, marking by clicking, with maximum of three markers placed on a maximum of three different locations in Zagreb. The respondents have been instructed to use the zoom option and to be as precise as possible with their mapping.

It is important to state that none of the non-spatial or spatial questions were mandatory for respondents to answer. After development, the instrument was tested before implementation and minor modifications to the questionnaire were done.

The final version of the questionnaire used for this research can be found in the Appendix 1 of this thesis.

3.4. Questionnaire administration

Since it was decided that the online questionnaire would be used, after its development described above, the application was uploaded onto Croatian Forest Research Institute's web-server and placed on a webpage with a unique URL (kartirajzelenilo.sumins.hr). At the opening page along with the welcoming messages and information about the aims of the questionnaire, a video (duration 1:50 min) was placed in which the PPGIS questionnaire and the process of mapping is described to potential respondents to facilitate their engagement. During the time of questionnaire administration, different ways of reaching broader public were used.

Invitations via e-mail were sent to the representatives of all community boards (*mjesni odbori* in Croatian) as a level of self-government in Zagreb. There are 218 community boards across the whole city. After initial invitation sent to them, second invitation after 2 months was sent to those community boards that did not respond to the first invitation. The invitation asked community boards' representatives to partake in the research and forward the information about the PPGIS questionnaire to their constituency. This way city-wide coverage was achieved ensuring that inhabitants of all city districts and subsequent smaller units had the opportunity to partake in the research. Except community boards, e-mail invitations were sent to professional societies in the field of forestry and urban forestry, and other citizen's organizations such as associations of retirees, sport organizations, volunteer fire departments, cultural associations, city administration offices, faculty personnel, museums personnel, protected areas personnel, different civil organizations, companies, students, and more. At the same time, the questionnaire was promoted through social media on personal social network profiles and official profile of the CULTUR-ES project targeting interested citizens that are not gathered around any of the above-mentioned organizations. Furthermore, regular posts with a picture and a text invitation were posted in local groups on social media, i.e. groups of people living in the same neighbourhood, or gathered around a common interest. Information about the questionnaire was in addition shared through different newsletters to a wider audience. Questionnaire was also promoted with attendances and talks at the scientific and professional conferences in the city of Zagreb. Finally, personal contacts were used to promote and distribute the questionnaire.

Monetary or any other form of compensation was not offered to stimulate participation.

3.5. Data analyses

Data collection ended on 11th November 2021 with the last entry to the database. All collected data was then downloaded from the database and exported into an Excel file. From the Excel file data is further imported into software as needed in an appropriate form. Softwares used for all further analyses were QGIS 3.16.14-Hannover for spatial analyses and visualisation and *R* software version 4.1.2 "Bird Hippie" with RStudio for statistical analyses and data visualization.

Packages used within *R* for data analyses were *base* (R Core Team, 2021), *tidyverse* (Wickham et al., 2019), *FactoMineR* (Lê et al., 2008), *factoextra* (Kassambara and Mundt, 2020), *rstatix* (Kassambara, 2021), *FSA* (Ogle et al., 2022), *BiodiversityR* (Kindt and Coe, 2005), *summarytools* (Comtois, 2021), *modelsummary* (Arel-Bundock, 2022), *officer* (Gohel, 2022), *flextable* (Gohel, 2022), and *psych* (Revelle, 2021).

Since data collected with PPGIS questionnaire consist of different types of data with spatial and non-spatial being the general differentiation among them, further employed analyses were in accordance with their type. However, when possible, data types were combined to gain more information and enhance interpretation and conclusions reached.

Analyses of spatial data collected with PPGIS questionnaire performed within this work follow analytical framework presented in Fagerholm et al. (2021a). Analyses will follow and refer to the three main phases in PPGIS spatial data analysis. Three main phases are: *Explore*, *Explain*, *Predict/Model* (Fagerholm et al., 2021a). Based on proposed aims for this research, data analyses will mostly cover the *Explore* and *Explain* phases to describe and interpret the data collected with *MyDynamicCity* Zagreb PPGIS questionnaire.

3.5.1. Spatial data analyses

Preparation of the secondary vector spatial dataset and classification of UGI types in Zagreb

For the purpose of delineating and categorizing different UGI types in the city of Zagreb two spatial datasets were procured, obtained, and combined using GIS software.

Two spatial datasets used for this purpose are:

1. Land Use 2020 dataset provided by the City Office for Economy, Environmental Sustainability and Strategic Planning of the City of Zagreb
2. Green Cadastre dataset provided by "Zrinjevac" company made available to use by the City Office for Reconstruction, Development, Physical Planning, Construction, Utility Services and Transport of the City of Zagreb

Spatial data collected with PPGIS questionnaires is usually analysed using pre-existing vector spatial datasets among which LC and LU datasets are most often utilised for the purpose (Fagerholm et al., 2021a). Those spatial datasets provide local context and allow for the interpretation of the collected spatial data. Commonly open and easily accessible spatial datasets are used for data analysis and interpretation such as CORINE Land Cover dataset produced by Europe's Copernicus Programme. Usually for large cities such as Berlin this kind of data is sufficient for distinguishing different types of green spaces (see Rall et al., 2017). For a relatively small city like Zagreb, spatial resolution provided by such dataset is not sufficient for distinguishing different types of UGI to a satisfactory degree. Zagreb's LU dataset provides the most recent and detailed spatial dataset regarding different LU categories in the city. LU dataset in a vector format (polygon geometry) is employed for the analysis of UGI in the city of Zagreb. Additionally, LU dataset is further enhanced with the Green Cadastre dataset.

The Green Cadastre dataset is compiled of several separate shapefiles, that is, tree dataset (point geometry), shrub dataset (polygon geometry), hedgerows dataset (line geometry), trail dataset (polygon geometry), playground surface dataset (polygon geometry) and equipment dataset (point geometry). Only selected elements of the dataset are employed within this research.

UGI classification extracted from the LU dataset alone was firstly tested with collected spatial data. Based on the results of analysis it was decided to use Green Cadastre dataset to enhance some of the existing LU categories and consequently provide a classification in a way that the results can be employed further.

LU dataset was utilized as a base vector layer onto which the UGI classification is built. Combination of LU and Green Cadastre datasets enabled calculations on woody vegetation data indices for different LU categories and defining new UGI types which are used further as a secondary vector dataset. The number of trees and shrubs inside each LU polygon was calculated, along with the number of unique species of trees and shrubs that are present. For

that purpose, QGIS software was used. Since the woody vegetation (trees and shrubs) are presumed as important, new column in an attribute table called “bin-green” was introduced and presented as a binary coded variable. If in one LU polygon there is data about either a tree, a shrub, or both entries, it is coded 1, indicating the existence of woody vegetation, contrary it is coded 0.

For defining one specific UGI type that was highlighted as important in previous, qualitative work, on cultural ecosystem services in Zagreb – tree alleys, different approach was applied. Tree alleys shapefile was extracted from the initial trees shapefile from the Green Cadastre dataset. In the attribute table of tree points in the Green Cadastre dataset, several categories of attributes are present. Among them composition category indicated the composition of trees in a space. One of the defined compositions is a tree alley. Trees in a tree alley composition were filtered out and extracted from the original data. Those points were further buffered with a 7 m buffer that warranted overlapping of near points and shaping a tree alley like polygons. Buffered points were dissolved into one polygon and then ‘*Multipart to Singlepart*’ algorithm in QGIS was used to separate vector layer in smaller parts – tree alleys. Newly created vector layer of tree alleys was then used in union with the existing UGI dataset, creating new UGI category employed further. The existence of a tree alley inside LU polygon is binary coded within the dataset as a new column in an attribute table called ‘bin-treealley’.

Before UGI classification in the city of Zagreb, polygons representing grey infrastructure, such as roads and railways, were removed from the LU dataset to facilitate classifying. For defining UGI types employed within this research, ‘*Field Calculator*’ in QGIS is used where UGI types are defined by function based on the characteristics found in original spatial datasets. Conditions used in the function are presented in Table 2.

Table 2 Conditional formatting used for UGI classification in the city of Zagreb

```
case
  when "Koristenje" = 'Park' then 'Park'
  when "Koristenje" = 'Suma' then 'Forest'
  when "Koristenje" = 'Park suma' then 'Park forest'
  when "Koristenje" = 'Groblje' then 'Cemetery'
  when "Koristenje" = 'Sport bez gradnje' then 'Sport field'
  when "Koristenje" = 'Sport s gradnjom' then 'Recreational facility'
  when "Koristenje" = 'Ostalo' then 'Other'
  when "Koristenje" = 'Gradski vrt' then 'Community garden'
  when "Koristenje" = 'Botanicki vrt / Zooloski vrt' then 'Botanical/Zoo garden'
  when "Koristenje" = 'Rekreacija u PP Medvednica' then 'Forest'
  when "Koristenje" = 'Neiskoristene izgradene povrsine - brownfield' then 'Brownfield'
  when "Koristenje" = 'Park za pse' then 'Dog park'
  when "Koristenje" = 'Rasadnik' then 'Nursery'
  when "Koristenje" = 'Igraliste' then 'Playground'
  when "Koristenje" = 'V1- Vode' then 'Water feature'
  when "Koristenje" = 'V2- Vode' then 'Water feature'
  when "Koristenje" is NULL and "bin-treealley" = '1' then 'Tree Alley'
  when "Koristenje" = 'D1- Upravna' and "bin-green" = '1' then 'Institutional green'
  when "Koristenje" = 'D2- Socijalna' and "bin-green" = '1' then 'Institutional green'
  when "Koristenje" = 'D3- Zdravstvena' and "bin-green" = '1' then 'Institutional green'
  when "Koristenje" = 'D7- Kulturna' and "bin-green" = '1' then 'Institutional green'
  when "Koristenje" = 'D8- Vjerska' and "bin-green" = '1' then 'Institutional green'
  when "Koristenje" = 'D6- Visokoskolska' and "bin-green" = '1' then 'Institutional green'
  when "Koristenje" = 'D5- Skolska' and "bin-green" = '1' then ‘Greenery of Educational Facility’
  when "Koristenje" = 'D4- Predskolska' and "bin-green" = '1' then ‘Greenery of Educational Facility’
  when "Koristenje" = 'D- sve' and "bin-green" = '1' then 'Public green areas'
  when "Koristenje" = 'Stambena i mjesovita' and "bin-green" = '1' then 'Greenery around
  residential buildings'
  when "Koristenje" = Poslovna' and "bin-green" = '1' then 'Greenery around business areas'
end
```

It is important to emphasise here how Green Cadastre dataset covers only those features that are under management of Zrinjevac company, hence not all trees in the city of Zagreb. For this research, the level of distinguishing among UGI types that was achieved combining the two datasets was satisfactory. However, it should be highlighted that the distinguishing level was sometimes limited by the amount of Green Cadastre data. Where this data was non-existent or not necessary (for forests and park forests for example), the LU dataset was used as the main data source for defining the UGI type.

When the UGI classification was finished and types defined, polygons that did not represent defined UGI types were removed. This supported the analyses in a way that spatial markers falling outside UGI polygons were not accounted for, but at the same time they were not manually removed by the researcher, granting an objective approach toward inclusion or exclusion of spatial markers from further analyses. After defining the UGI types, all spatial analyses used a subset of spatial markers that were placed in some of the defined UGI types. All analyses within this thesis along with data used for each are presented in Figure 6 to facilitate further reading on data analysis.

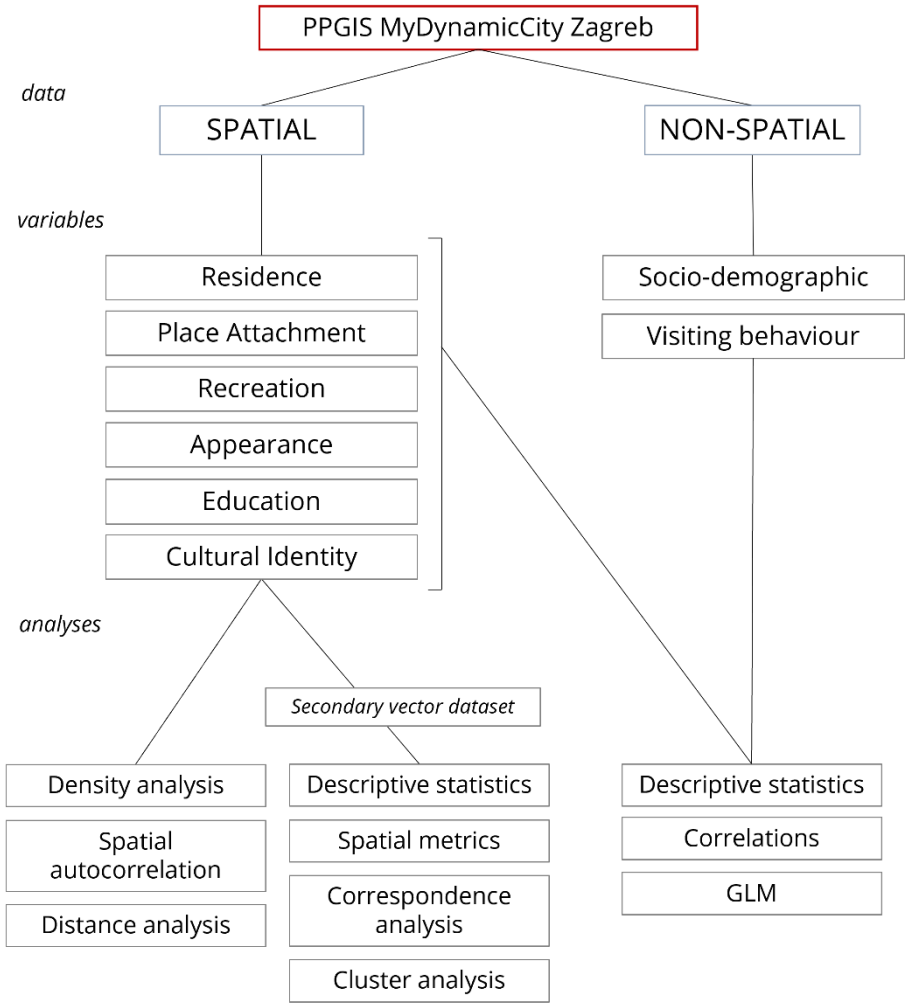


Figure 6 Flowchart outlining data, variables and methods used for analysis of spatial and non-spatial data collected with MyDynamicCity Zagreb PPGIS questionnaire

Descriptive statistics on collected spatial data

Following the spatial data preparation and UGI classification, collected spatial markers with PPGIS questionnaire were intersected with the prepared secondary vector spatial dataset in a QGIS software. Before that, three-step pre-processing at non-spatial and spatial data was performed to ensure that only the target population and target areas in the city of Zagreb were included into analysis. For each specific attribute, the number of points in polygons were counted and afterwards aggregated by a UGI type on a city level. The result of this analysis is the number of collected spatial markers by attribute of cultural ecosystem service or disservice in classified UGI types. Only spatial markers that can be attributed to a defined UGI types were used in further analyses. Those spatial markers that fell outside the defined categories were excluded because it is believed that classification covers different UGI types well enough and

that spatial markers placed outside previously defined categories are not objective of this research.

Descriptive statistics is presented as the frequencies of spatial markers collected with *MyDynamicCity* Zagreb PPGIS questionnaire.

For each category and attribute of cultural ecosystem services and disservices the aggregated number of collected spatial markers with PPGIS questionnaire was calculated, along with the number of markers placed into defined UGI types, and the number of respondents who placed markers of a respective attribute in defined UGI types in Zagreb.

Spatial metrics

Spatial metrics consists of the data about intensity, richness, and diversity of the collected spatial markers (Brown and Fagerholm, 2015; Plieninger et al., 2013). These metrics are often used when analysing PPGIS spatial data because they allow easy quantification of mapped data across the study area, while simultaneously enabling comparison between different spatial units used within the study (Brown and Fagerholm, 2015). Spatial metrics indices are calculated with point dataset representing all the collected spatial markers included in the analysis. This approach is based on and adapted from similar approaches found in scientific literature on the PPGIS data analysis (see Fagerholm et al., 2019; Plieninger et al., 2013).

Intensity refers to the total number of spatial marker points placed for one UGI type across the whole city. Richness was defined as the number of different attributes placed for one UGI type across the whole city. Diversity was calculated with Shannon Diversity Index to analyse diversity and occurrence of the explored attributes across the study area for each UGI type (Brown et al., 2018; Fagerholm et al., 2012). The Shannon Diversity Index is commonly used in ecology to measure species' diversity in the community, but also within the scope of social-ecological research where it is utilized as one of the methods used with PPGIS spatial data to assess diversity and evenness within the distribution of attributes (often different ecosystem services) mapped (Brown et al., 2014). The calculation of spatial metrics for Zagreb's dataset was made using the *R* software, where *BiodiversityR* package was used to calculate the Shannon Diversity Index. Input data (polygon and point vector layers and their respective attribute tables) for the analysis were exported from QGIS software into CSV files and imported into *R* for further processing.

Multivariate

Multivariate statistic allows for simultaneous exploration of a multitude of variables; hence, it is one of the more powerful tools employed within exploratory data analysis. When the variables of interest are categorical, then correspondence analysis (CA) or multiple correspondence analysis (MCA) can be employed. CA was used to explore the relationships between attributes of perception of cultural ecosystem services and disservices in relation to the defined UGI types in the city of Zagreb. The CA as a statistical method was chosen because its primary goal is to show graphically the most important relationships among variables. The method does not require any underlying distributional assumptions to be met, allowing any categorical variable to be used. Furthermore, categorical features are preserved because the level of response is used in the analysis (Sourial et al., 2010). For conducting CA, a contingency table consisting of a number of spatial markers holding attributes of cultural ecosystem services and disservices within each UGI type was constructed. The contingency table was tested for independence among variables employing the Chi-square test of independence with level of significance being $p < .05$ using Monte Carlo simulation with 2000 replications to detect whether variables are independent or there is dependency among them that in turn allows conducting CA.

The result of CA is a two-dimensional graphical representation of relative frequencies presented as a distance between rows and columns in a contingency table, along with distances of every variable to the average row and column profile, thus allowing detection and interpretation of possible clusters between variables (Bachi et al., 2020; Sourial et al., 2010). Multivariate analysis was conducted using *FactoMineR* package for calculating CA and *factoextra* package for visualizing the results within the *R* software.

Density analysis of collected spatial markers

Kernel density estimation is a nonparametric technique for estimating the probability density function of a random variable (i.e., landscape value) based on observed point locations (Brown and Pullar, 2012). Producing maps of collected spatial markers across the AOI allows for exploration of the relationship between the mapped data and underlying geospatial data, and it is part of the *Explore* phase in the spatial data analysis (Fagerholm et al., 2021a). Hotspot maps are regularly produced within PPGIS research because they are visually attractive and easy to

interpret for stakeholders. Results of density analysis are a natural extension to other analyses because they provide a spatial context.

Kernel density estimation calculation is commonly used with PPGIS data to visually investigate and represent the collected point data on a map in a raster form (Bachi et al., 2020; Baumeister et al., 2020; Beckmann-Wübbelt et al., 2021; Rall et al., 2017). The result of employing Kernel density analysis is a raster representing a spatially continuous surface of intensity/density of the mapped attribute on a map (Fagerholm et al., 2021a). The most important variables that need to be defined while producing Kernel density estimations are the search radius around points and the output pixel cell size. Since there are no defined thresholds, search radius and pixel size usually depend on the spatial data collected with PPGIS questionnaire and it is for the researcher to decide which radius and pixel size will best suit the need of exploratory data analysis.

Hotspots in the scope of this work are locations and subsequently types of UGI where a specific attribute of cultural ecosystem service or disservice was highly spatially perceived (mapped). Density analysis was performed on the number of spatial markers placed in UGI types.

Hotspot maps for the city of Zagreb were produced using '*Kernel density estimation*' algorithm in a QGIS software. Based on a previous similar PPGIS research, inputs for creating density raster were 600 m for a search radius around points and 50 m in output pixel size using quadratic function. A separate map was created for each of the explored cultural ecosystem service and disservice perception attributes. The map outputs were visualized using equal interval classification between the calculated values with classes 4 to 10, depending on the number of mapped points, following the work of Baumeister et al. (2020). City boundaries used for producing maps were taken from LU vector dataset that was made available for use by Zagreb's City Office for Economy, Environmental Sustainability and Strategic Planning. As s base map for produced cartographic representations, digital orthophoto of the city of Zagreb is used, made available to use by Croatian Geodetic Administration.

Distribution of collected spatial points and spatial autocorrelation

Spatial data validation can be external and internal. While external data validation assesses representativeness of the gathered sample of population and capability of utilizing the employed methods to other contexts, internal data validation is concerned with the collected

spatial data quality (Fagerholm et al., 2021a). Assessing positional accuracy, correctness, and completeness validity alongside testing for spatial autocorrelation are commonly used approaches in determining internal spatial data validity (Fagerholm et al., 2021a). Accuracy of the collected spatial data in Zagreb was tested by overlaying prepared secondary spatial dataset containing UGI type classification with collected spatial markers.

Spatial autocorrelation is the measure of correlation of the same attribute at different locations. When there is a positive spatial autocorrelation among attributes, spatial proximity is bonded where similarity in attribute values creates clusters of values (Schabenberger and Gotway, 2020). One of the most used methods to test PPGIS data for spatial autocorrelation is calculating the nearest neighbour (NN) index (Fagerholm et al., 2021a, 2019; Van Riper and Kyle, 2014). The result of employing NN statistic is an information about the pattern distribution that collected PPGIS spatial markers display on a map (Fagerholm et al., 2016). NN statistic compares the calculated distances between the collected points and hypothetical randomly distributed point shape within the study area to detect possible patterns.

To test for spatial autocorrelation in this research NN index was calculated for spatial markers collected with PPGIS questionnaire in the city of Zagreb. Separate calculation was made for each attribute of cultural ecosystem services and disservices and for all collected spatial markers altogether regardless of the attribute. For calculating NN values QGIS software and '*Nearest neighbour analysis*' algorithm were used. The result of NN analysis are values representing the observed mean distance between points, expected mean distance between points, NN index value and Z-score. When the NN index value is lower than 1, points can be described as spatially clustered, while value larger than 1 indicates spatial dispersion of points of interest. Z-score indicates the number of standard deviations of the value from the mean index.

Distance analysis

Distance analysis was carried out for each cultural ecosystem service and disservice attribute separately. Previous research showed that there are differences among distances from respondent's place of residence and the location of perception of different cultural ecosystem services (Beichler, 2015; Fagerholm et al., 2019, 2016). Likewise, variation in distance from the respondent's home can help to understand and interpret spatial patterns that emerged in the spatial data collected with the PPGIS questionnaire (Fagerholm et al., 2019). Therefore, to test

the part of hypothesis that perception is based on distance from the respondent's home, distance analysis was employed on collected spatial markers. As mentioned, the respondents were asked to mark the quadrant where their home address was located. Hence, analysis could be done only for those respondents who marked their place of residence and placed at least one spatial marker of perception on a map further in the questionnaire. To ensure anonymity, the exact home address was not asked from the respondents, only the quadrant, which is why for distance analysis the centroid of a marked quadrant represented home address. Linear distance in meters was calculated between centroids and spatial markers that were placed on the map. Linear distance does not take into consideration the complexity of space (i.e., streets) (Chiang and Li, 2019). However, it is a good approximation of distance to determine where some cultural ecosystem service is perceived (De Valck et al., 2016). Using '*Distance matrix*' algorithm in QGIS software, the matrix of calculated distances was created between the two vector point datasets (centroid and a subset of spatial markers representing a specific attribute of perception placed in one of the UGI types), with *userid* as the ID field serving as a connection between them. The resulting distance matrix was exported as a CSV file from QGIS and imported into the *R* software. Since distance matrix contains distances between all points from the layers used as an input for analysis, a subset of distances was made to represent only those distances where *userid* of centroid points is equal to *userid* of the spatial marker placed on a map, allowing the analysis on a respondent level. Descriptive statistic was calculated for measured distances and presented with measures of central tendency and dispersion. The results include measures of central tendency and dispersion - minimum, maximum, mean, median and standard deviation values together with a number (N) of points included in the analysis. Due to an uneven number of spatial markers collected for each cultural ecosystem service and disservice category, and based on results reported in similar studies in scientific literature, the median value seems to be a more suitable indicator of stated preference, that is, the distance one is willing to cross to engage in recreational activity or specific experience (De Valk et al., 2016). For that reason, the calculated median values were reported. Box-plot graph of measured distances was produced to visually inspect the possible differences among distances by each attribute.

To test for differences among calculated distances for cultural ecosystem services and disservices, the Kruskal-Wallis test for differences among groups was used. To further analyse possible differences between the pair of groups, Dunn's post-hoc test with Bonferroni correction was employed. *R* statistical software including *rstatix* and *FSA* packages was used for the Kruskal-Wallis and Dunn's post-hoc tests.

Cluster analysis

The existence of urban-rural gradient in the city of Zagreb was explored using frequencies of mapped spatial markers of specific attributes representing cultural ecosystem service and disservice category in relation to the city district in Zagreb. Spatial markers representing each cultural ecosystem service, as well as a disservice attribute, were counted separately in polygons holding information about the UGI type and the respective city district in QGIS. The results were exported into a CSV file and imported into the *R* software. Using the *R* software, count data were aggregated on the city district level. As a result, contingency table was created for cultural ecosystem services and disservices' occurrence in each city district, separated by the city district and an attribute. This table was used to further explore the urban-rural gradient.

To detect possible similarities within city districts and mapped perception of UGI, hierarchical clustering analysis (HCA) was performed using the Euclidean distance and Ward's agglomerative method for data visualization, following the similar approach presented as in Plieninger et al. (2013). Cartographic visualization on the counted aggregated number of spatial points for each city district was created in QGIS. The number of collected spatial markers in a cartographic visualization was presented with five categories and natural breaks between the frequencies to facilitate the interpretation of the clustering results.

3.5.2. Non-spatial data analyses

Descriptive statistic on the socio-demographic characteristics of respondents

To explore the sample of population and conclude on its representativeness, firstly the descriptive statistics on the collected socio-demographic data was given. Numerical variables collected with open-ended question are presented with measures of central tendency and dispersion (minimum, maximum, mean, standard deviation), while categorical variables are presented as frequencies of a given answers to close-ended questions. Data used for this analysis was collected with open- and close-ended questions in the PPGIS questionnaire before the mapping exercise. Data on socio-demographic characteristic of the respondents was exported from the excel database as a CSV file and imported into the *R* software. Using *summarytools* package within the *R* software, descriptive statistic was calculated on the sample.

Descriptive statistic on the respondents' visiting behaviour in relation to green spaces in Zagreb

Descriptive statistic on visiting behaviour towards green spaces in Zagreb is presented with measures of central tendency and dispersion (minimum, maximum, mean, standard deviation) for numerical variables as answers to open-ended questions and frequency tables for categorical variables as answers to close-ended questions in the questionnaire. Data used for this analysis was collected upfront by mapping part of the questionnaire with the aim to further enhance the interpretation of the gathered sample and gain better insight into respondents' visiting behaviour and preferences toward visiting urban green spaces in Zagreb.

Sample representativeness

Concluding on the sample representativeness is part of the external spatial data validation (Fagerholm et al., 2021a). Sample representativeness can be calculated based on spatial distribution of the people who participated in the study and likewise on their main socio-demographic characteristics.

Within this research sample's spatial distribution is represented with the number of respondents participating from distinct city district in Zagreb. The number of respondents in a city district was calculated based on the number of spatial markers placed for the residence in each of the polygons marking a city district in Zagreb. When the spatial data was unavailable, then the answer to a closed-ended question about the city district was the one used. Testing for spatial representativeness was determined by comparing the proportions of the respondents in the questionnaire with the proportion of Zagreb's residents living in the same city district using Chi-square statistics.

Statistical Yearbook of the City of Zagreb (SYCZ) 2021 was used as a relevant and up to date data source to compare the important variables and to bring a conclusion regarding the sample representativeness.

Representativeness of the gathered samples based on their socio-demographic characteristics was determined by comparing proportions of the respondents and their main socio-demographic variables with the general population for the city of Zagreb. Socio-demographic variables used for detecting representativeness were gender, age group and highest achieved level of education.

Correlation among non-spatial variables

Sets of correlation matrices were produced to test the relationship among the quantity of mapped attributes of cultural ecosystem services and disservices among the respondents with different socio-demographic characteristics and visiting behaviour. Frequencies of each mapped spatial marker attributes were calculated in relation to categorical socio-demographic data. Socio-demographic variables used were gender, age group, highest achieved level of education and employment status. For each variable a separate contingency table was prepared and used for calculating correlations.

Likewise, frequencies of mapped spatial marker attributes were calculated in relation to visiting behaviour that the respondents expressed. The chosen variables included visiting frequency, part of the day, part of the week and the duration of one visit. Contingency tables were prepared and used further to produce separate sets of correlation matrices.

Procedure of data preparation and correlation calculation was conducted within the *R* software. Spatial data included into the analyses was exported from QGIS into a CSV file and imported into the *R* software. Spatial and non-spatial data were connected based on a common unique variable between the datasets – *userid*. Spearman rank order correlations were calculated between categorical variables employed for the analyses. For correlation matrices, *psych* package was used and the results were presented with statistical significance $p < .01$.

Generalized linear models (GLM)

Generalized linear models (GLM) are an extension of the basic linear models, but unlike the classical linear models, GLM do not assume normal distribution of the dependent variable (Dobson and Barnett, 2018). Therefore, they are plastic enough to be used with count data, and as such are utilized with PPGIS data to explore relationships among variables (Dade et al., 2020; Fagerholm et al., 2019; Rall et al., 2017). However, GLM is one of the rarely employed statistical approaches used on PPGIS data to identify and explore the relationship among different non-spatial variables and mapped attributes and as such represents an advanced approach to the *Explore* phase of the PPGIS data analysis. Since similar approaches were found in the scientific literature, where GLM were constructed on the count data to explore the relationship among variables, the decision was made to use GLM to model the stated spatially explicit perception and to explore the relationship between chosen socio-demographic and visiting behaviour variables with the amount and type of spatial markers placed on a digital

map by respondents within this research. The aim of the analysis is to examine possible relationships among chosen mapped spatial attributes and non-spatial variables.

GLMs were constructed to model the frequency of placed spatial markers in defined UGI types in Zagreb as a function of the respondents' socio-demographic data and stated visiting behaviour. Since socio-demographic data is shown to influence the perception of cultural ecosystem services and disservices of UGI to some extent (Baumeister et al., 2022; Plieninger et al., 2013), gender, age group, highest achieved level of education and employment status were used as relevant socio-demographic variables. On the other hand, visiting frequency, part of the day, part of the week, average duration of visit to green space and company of the respondent while visiting green spaces were used as relevant visiting behaviour variables. All the independent explanatory variables used are categorical.

A separate model was constructed and run for each explored cultural ecosystem service or disservice attribute, with the corresponding number of spatial markers collected as a dependent variable and non-spatial data collected from the respondents as independent variables. Since the data on the spatial markers mapped is count data, the Quasi-Poisson error distribution was used to fit the assumption of GLM (Rall et al., 2017). Significance level used for interpretation of variables was $p < .05$. GLMs were constructed in the *R* software using *base* R, while tables of the model results were plotted using *modelsummary* package.

4. RESULTS

4.1. Descriptive statistics on collected spatial markers

In total 6,673 spatial markers were collected with *MyDynamicCity* Zagreb PPGIS questionnaire. This number represents all collected spatial data before pre-processing. Pre-processing included spatial data cleaning, filtering, and reducing to a final number which was used further for analyses.

Data cleaning was performed in three steps. The first step was to remove spatial data that was placed outside the city of Zagreb's administrative borders. Throughout the whole questionnaire green spaces in the city of Zagreb were highlighted as places of interest; however, other places outside the official boundaries were marked by the respondents. Therefore, the first data cleaning resulted with points located in the city of Zagreb. In the second step double entries were found and removed from the database (spatial and non-spatial), along with those respondents who indicated place of residence outside the city of Zagreb or whose socio-demographic profile did not match the target population. Results of the second step of data cleaning are presented in Table 3 within 'Collected marker' column. Hence, this number represents all collected spatial markers from the target sample including the citizens of Zagreb aged 18 and older who placed spatial markers anywhere within the city of Zagreb. 'Analysed marker' column in Table 3 represents those spatial markers placed in defined UGI types. This category is a result of the third step of pre-processing, when spatial markers that were not placed in defined UGI types were not used for further analyses.

The 'Respondents' column represents the number of unique respondents who used a specific attribute in their mapping exercise and placed them in a defined UGI. The highest number of respondents used markers for Place of Residence, Place Attachment, Education and Cultural Identity. Those were also the mapping categories where there was no attribute to choose from in mapping questions. Since none of the mapping questions were mandatory for the respondents to answer, the number of the respondents varies from 370 for Place Attachment to 323 for Education. For those categories where the respondents could choose an attribute to place on a map, the number of respondents is lower and ranges from 21 for Conflicts as disservices' attribute to 300 respondents for Walk as a recreational activity attribute indicating importance of this recreational activity for the people in the sample. 369 respondents mapped Recreation as a cultural ecosystem service regardless of the attribute. Further, the respondents to a large extent selected attributes of the cultural ecosystem service category of Aesthetics,

where each was chosen by more than 220 respondents. On the other hand, the respondents selected attributes of Disservices to a lesser extent. For instance, only 39 respondents mapped green spaces which they perceive as Scary and 118 decided to mark green spaces perceived as Unmaintained places. 351 respondents chose to map Aesthetics and 194 to map Disservices. 365 respondents in total mapped attributes in the appearance category regardless of the attribute. On average, a respondent placed 15 markers on a digital map in a mapping exercise.

Table 3 Descriptive statistics of the collected spatial markers with the PPGIS questionnaire in the city of Zagreb, along with the number of respondents that mapped each attribute

CES/Disservice	Collected marker (N)	Analysed marker (N)*	Respondents (N)
Place of residence	373	373	373
Place Attachment	958	935	370
R/Bike	205	185	145
R/Dog	161	145	100
R/Hike	150	137	125
R/Kids	148	139	96
R/Nature Watching	142	138	114
R/Run	123	115	97
R/Social	281	268	212
R/Walk	535	506	300
A/Experiences	293	271	223
A/Maintained	290	280	224
A/Naturalness	379	368	278
A/Restorative	366	353	272
D/Conflicts	22	22	21
D/Noisy	127	116	102
D/Scary	50	45	39
D/Unmaintained	160	150	118
Education	753	733	323
Cultural Identity	881	851	350

*Number of analysed points for cultural ecosystem services/disservice represents the number of spatial markers placed in defined UGI types

4.2. Delineated urban green infrastructure types and descriptive statistics on the number of collected spatial markers

The preparation of secondary vector spatial dataset and the classification used for analyses of UGI in GIS resulted with 20 different types of UGI in the city of Zagreb. It should be noted that this classification is not official, but rather developed for the purpose of this work. However, it fairly well represents different UGI types in the city of Zagreb.

Defined UGI categories include the following: Botanical/Zoo Garden, Brownfield, Cemetery, Forest, Greenery of Educational Facilities, Greenery around Residential Buildings, Institutional Green, Nursery, Other, Park, Park Forest, Public Green Area, Recreational Facility, Sport Field, Treeline, Water Feature, Community Garden, Greenery around Business Areas, Dog Park and Children's Playground.

The mapping exercise in *MyDynamicCity* Zagreb PPGIS resulted in total with 5,757 spatial markers collected and included in the analyses. The distribution of spatial markers collected for each cultural ecosystem service and disservice category and attributes across all defined UGI types is presented in Table 4. The respondents placed the highest number of spatial markers in the UGI category of parks (2,828), almost three times less in forests (1,098) and in park forests (644), indicating their importance as part of broader green infrastructure for the city of Zagreb. Examining the further distribution of collected markers for parks showed that parks were perceived mostly as bearers of Cultural Identity, representing the most abundant cultural ecosystem service category found for parks, followed by Place Attachment (538 and 474 spatial markers respectively). Parks were also perceived as partly Unmaintained places; however, these markers represent only 1% of all collected markers for parks. All explored attributes of cultural ecosystem services and disservices were places in parks on a city level.

Forests, the category of UGI with the second highest number of collected spatial markers, are largely perceived as bearers of Place Attachment service and offer opportunities for Education in nature, hence those are the most abundant categories of the collected spatial markers. Furthermore, Hiking as recreational activity is almost exclusively attached to forests. Interestingly, both forest and parks were equally perceived as green spaces where one can experience the perception of Naturalness for which spatial markers are evenly distributed. Alike parks, the respondents also perceived all explored cultural ecosystem services and disservices in forests.

Park forests were alike forests perceived among the respondents as their favourite green spaces, indicating attachment to those places, and as green spaces with educational potential. However, it should be emphasised that even though forests are abundant across the city of Zagreb and are the main feature of Medvednica Nature Park, park forests were more associated with the perception of Cultural Identity than forests based on the number of collected markers.

The UGI category of Other was transferred from the original spatial dataset where it is defined as "Agricultural Areas, Unmaintained Areas, Protective Green and Other". Even though it was not as strict category as other UGI categories, it was expected that these areas would be equally important for the citizens of Zagreb and partake in the perception and use of green spaces. The results confirmed this assumption based on the number of spatial markers collected for other land uses (424). The most often selected attributes were Place Attachment, Walking, Education, and perception of Unmaintained places. However, the respondents perceived all explored attributes of cultural ecosystem services and disservices in this UGI type. Even though not as abundant, other land uses were marked as Scary places for some respondents.

Water features and related vegetation as a component of UGI were also an important part of perception and use of green spaces in Zagreb. Similar to other as a UGI type, water features did not have an overabundance of spatial markers for specific category or attribute, but rather all markers (except Hiking) were placed to some extent onto this UGI. Water features as a UGI type are spatially generated from combining water streams, standalone lakes (which are not part of park elements), and Sava River polygons with embankments around them. While some spatial markers were placed on polygons representing specifically the Sava River or one of the Savica Lakes, the number of those markers is not significantly large to be split into two categories. Furthermore, since there were no particular activities found which were related to specific water features, it was decided to keep the classification simple in this regard. Water features together with walking paths around them are treated therefore as equally important for the provision of cultural ecosystem services and disservices. Most frequently collected spatial markers for water features belong to Place Attachment category, indicating that those places are some of the favourite ones for the respondents. Walking and perception of those places as Restorative are the second and the third most abundant features.

The last UGI type with more than 100 spatial markers collected altogether is the Botanical/Zoo Garden. In an official LU dataset, those categories are also joined together and form one coherent LU type, that is one UGI category. The total number of spatial markers collected for

the Botanical/Zoo Garden type was 155, out of which collectively 105 markers were associated with Cultural Identity and Education. Visual inspection of the collected markers discovered that the more important UGI type of the two combined is the Botanical Garden, while only 8 spatial markers were placed in the Zoo Garden, indicating higher importance of the Botanical Garden for the respondents.

Each of the remaining 14 defined UGI types collected in less than 100 spatial markers across all cultural ecosystem services and disservices attribute categories. The number of collected markers ranged from 1 for children's playground to 84 for greenery around residential buildings. For the latter, the respondents mapped mostly Place Attachment, which point out the importance of those green spaces for the respondents and their everyday life. Greenery around residential buildings as the UGI type originated from combining LU and Green Cadastre datasets. Visual inspection of digital orthophoto imagery for the city of Zagreb underneath the newly delineated areas showed that there was a good link between spatial dataset and reality.

Table 4 Frequency table showing the distribution of collected spatial markers for cultural ecosystem services and disservices by attribute in every defined UGI type in the city of Zagreb

UGI type / CES/Disservice	**BZG***	**BRF***	**C***	**F***	**GEF***	**GRB***	**IG***	**NUR***	**OTH***	**P***	**PF***	**PGA***	**RF***	**SF***	**TA***	**WF***	**CG***	**GBA***	**DP***	**PLY***	***total***
Place Attachment	14	1	7	168	5	21	6	1	66	474	114	2	3	11	3	39	0	0	0	0	935
R/Bike	0	1	1	27	0	4	0	1	22	94	11	0	0	4	1	18	1	0	0	0	185
R/Dog	0	0	1	35	0	4	0	0	20	53	17	0	0	4	1	9	0	1	0	0	145
R/Hike	0	0	0	128	0	0	0	0	2	1	6	0	0	0	0	0	0	0	0	0	137
R/Kids	0	0	0	16	1	5	3	1	12	76	13	3	1	4	0	4	0	0	0	0	139
R/Nature Watching	7	0	0	53	0	0	0	0	12	45	16	0	0	0	0	5	0	0	0	0	138
R/Run	0	1	1	15	0	3	0	0	17	48	12	0	1	4	1	10	0	2	0	0	115
R/Social	3	1	1	41	1	6	3	1	24	149	19	1	2	4	5	6	0	0	1	0	268
R/Walk	3	0	5	91	2	8	4	0	46	229	78	3	0	9	3	25	0	0	0	0	506
A/Experiences	8	0	2	38	0	2	3	0	14	174	17	0	0	0	4	7	0	1	1	0	271
A/Maintained	3	1	1	20	1	3	1	2	17	195	18	0	0	5	5	7	0	1	0	0	280
A/Naturalness	4	0	0	133	0	2	2	0	14	133	62	0	0	1	2	15	0	0	0	0	368
A/Restorative	5	0	1	84	1	7	1	0	24	152	45	0	0	4	1	24	1	1	2	0	353
D/Conflicts	0	0	0	3	0	0	0	0	3	12	0	0	0	0	0	3	0	0	0	1	22
D/Noisy	3	1	1	5	0	4	0	0	6	81	1	1	1	3	3	5	0	0	1	0	116
D/Scary	0	2	0	4	1	2	1	0	9	13	2	1	0	2	0	5	1	2	0	0	45
D/Unmaintained	0	1	0	19	2	4	1	0	37	41	15	0	1	9	3	14	0	1	2	0	150
Education	60	1	13	139	3	1	6	1	44	320	107	1	3	8	1	23	1	1	0	0	733
Cultural Identity	45	3	16	79	1	8	2	0	35	538	91	4	1	8	3	16	0	1	0	0	851
total	155	13	50	1,098	18	84	33	7	424	2,828	644	16	13	80	36	235	4	11	7	1	5,757

*BZG = Botanical/Zoo Garden | BRF = Brownfield | C = Cemetery | F = Forest | GEF = Greenery of Educational Facilities | GRB = Greenery around Residential Building | IG = Institutional Green | NUR = Nursery | OTH = Other | P = Park | PF = Park Forest | PGA = Public Green Areas | RF = Recreational Facility | SF = Sport Field | TL = Tree Alley | WF = Water Feature | CG = Community Garden | GBA = Greenery around Business Area | DP = Dog Park | PLY = Children's Playground

4.3. Spatial metrics

For each defined UGI type, three common spatial metrics were calculated – intensity, richness and diversity. The results of these calculations are presented in Table 5. Intensity refers to the number of spatial markers placed in each UGI type in the city of Zagreb. Richness is the number stating how many different types of cultural ecosystem service or disservice attributes are placed inside a specific UGI type throughout the city of Zagreb, thus it indicates how multifunctional these places are. Diversity was calculated using the Shannon Diversity Index (*H*). Higher *H* index indicates higher diversity of perceived cultural ecosystem services or disservices in each UGI type in the city of Zagreb, meaning that the respondents perceived various cultural ecosystem services and disservices offered by each UGI type, while $H = 0$ means that the respondents perceived a certain UGI type as providing only one service or disservice.

The results showed that UGI types with the highest calculated intensity were parks and forests, followed by park forests. These three types of UGI together account for three quarters of all collected spatial markers regardless of their attribute. Alongside these, the categories of other, water features and Botanical/Zoo garden each had intensity higher than 100.

Out of 19 possible attributes presented to the respondents, they placed all of them in forests, parks, and other, while 18 in park forests and water features. Furthermore, higher richness of attributes was calculated for greenery around residential buildings, sport fields and tree alleys (16, 15 and, 13 attributes respectively). The lowest richness was found for playground, dog parks, and community gardens.

The highest diversity index is calculated for other, water features, forests, sport fields, and parks, with *H* being larger than 2.50, ranging from 2.51 for parks to 2.69 for other. Playgrounds had the lowest calculated Shannon Diversity Index ($H = 0.00$) because the respondents placed only one spatial marker in this UGI type, indicating one service found there (only one service perceived). Based on diversity (*H* up to 2), Botanical/Zoo garden, cemetery, nursery, public green areas, recreational facilities, community gardens and dog parks were placed somewhere in the middle.

Table 5 Calculated spatial metrics - Intensity, Richness and, Diversity - based on the collected number and attribute of spatial markers for every defined UGI type in the city of Zagreb

UGI type	Intensity	Richness	Diversity (H)
Botanical/Zoo Garden	155	11	1.74
Brownfield	13	10	2.20
Cemetery	50	12	1.89
Forest	1,098	19	2.56
Greenery of Educational Facilities	18	10	2.11
Greenery around Residential Building	84	16	2.49
Institutional Green	33	12	2.29
Nursery	7	6	1.74
Other	424	19	2.69
Park	2,828	19	2.51
Park Forest	644	18	2.42
Public Green Areas	16	8	1.93
Recreational Facility	13	8	1.95
Sport Field	80	15	2.56
Tree Alley	36	14	2.48
Water Feature	235	18	2.65
Greenery around Business Areas	11	9	2.15
Community Garden	4	4	1.39
Dog Park	7	5	1.54
Children’s Playground	1	1	0.00

4.4. Correspondence Analysis

Meaningful interpretation of the collected spatial data can be given with occurrence frequencies of cultural ecosystem service and disservice categories and attributes along UGI types in Zagreb that are supplemented with spatial metrics results. However, to better understand interactions between the explored cultural ecosystem services and disservices and classified UGI types marked as providers of specific services, correspondence analysis (CA) was performed.

The results of CA were presented graphically and tabularly. Table 4 (excluding the summarized numbers under *"total"*), represents the contingency table that was used as an input for CA. Prior to the CA, the table was tested for independence of variables using Chi-square test with Monte Carlo simulation (2000 replicates). Monte Carlo simulation was employed due to a large quantity of zero values of collected spatial markers for some UGI types. Hence, the results of Chi-square test without simulation cannot be used as true and relevant.

The results of Chi-square test of independence indicated that tested variables were dependent and that there is a relationship between them (χ^2 = 1935.5, *df* = NA, $p < .001$). Based on the Chi-square test of independence result, there was an indication that the distribution of specific spatial markers could be explained with different UGI types and vice versa. Therefore, CA was employed to test this relationship further.

The first and main result of CA was a biplot of calculated results. Biplot is a two-dimensional graphical representation of the two selected dimensions of results. The biplot is presented in Figure 7, and it shows the first two dimensions of CA results. Those first two dimensions together explained ~60% of total variability among the data from the contingency table used as an input. The first dimension explained 39.9% of variation, while the second explained further 19.8%. Explanatory power for the next five dimensions is presented in Figure 8 along with the percentage of variance explained with each of the first seven dimensions. After calculating the sixth dimension, the explanatory power of dimensions was below 3% and decreasing.

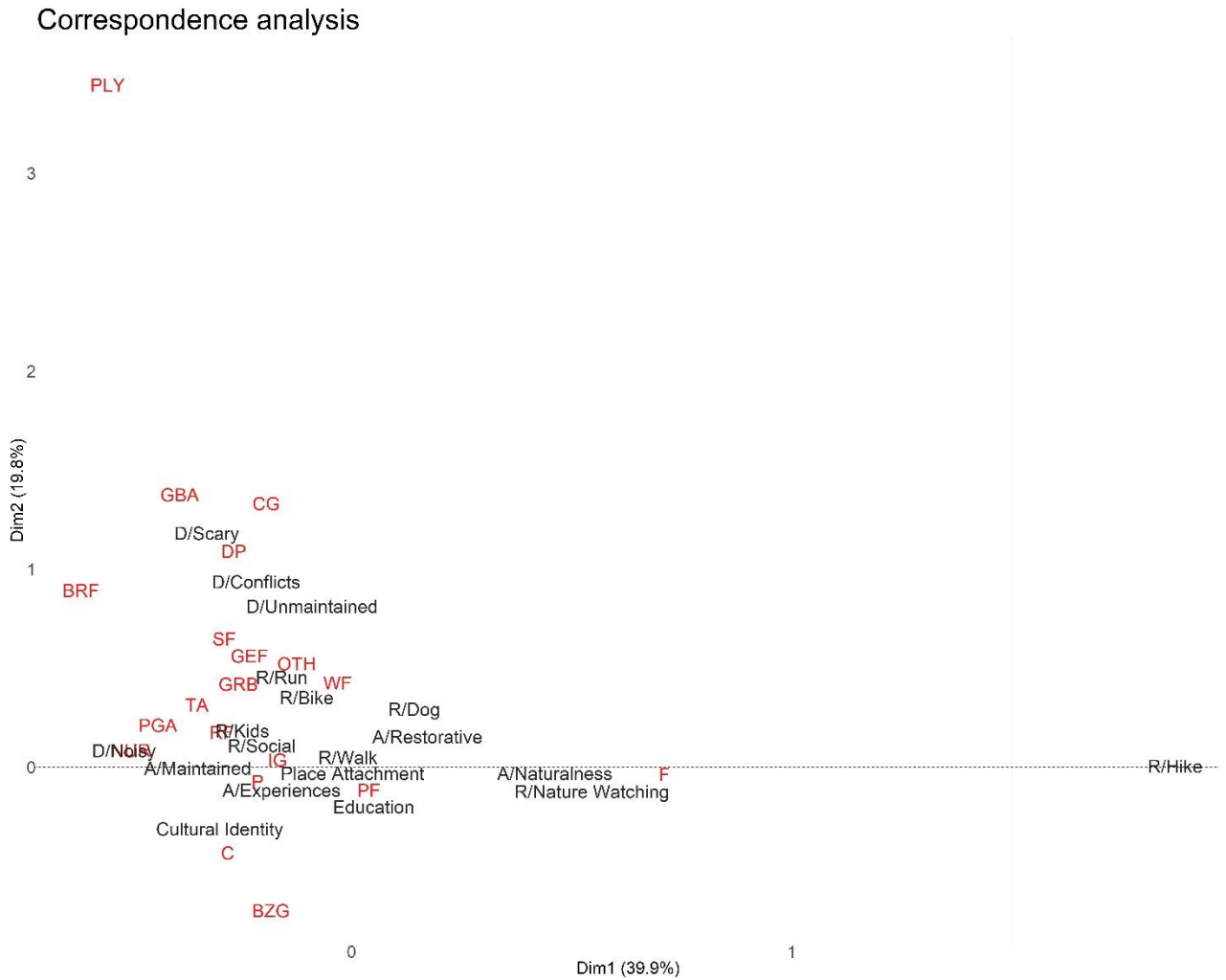


Figure 7 Biplot of correspondence analysis results (first two axes displayed) – UGI types in red, cultural ecosystem services/disservices in grey*

**BZG = Botanical/Zoo Garden | BRF = Brownfield | C = Cemetery | F = Forest | GEF = Greenery of Educational Facilities | GRB = Greenery around Residential Buildings | IG = Institutional Green | NUR = Nursery | OTH = Other | P = Park | PF = Park Forest | PGA = Public Green Areas | RF = Recreational Facility | SF = Sport Field | TA = Tree Alley | WF = Water Feature | CG = Community Garden | GBA = Greenery around Business Areas | DP = Dog Park | PLY = Children's Playground*

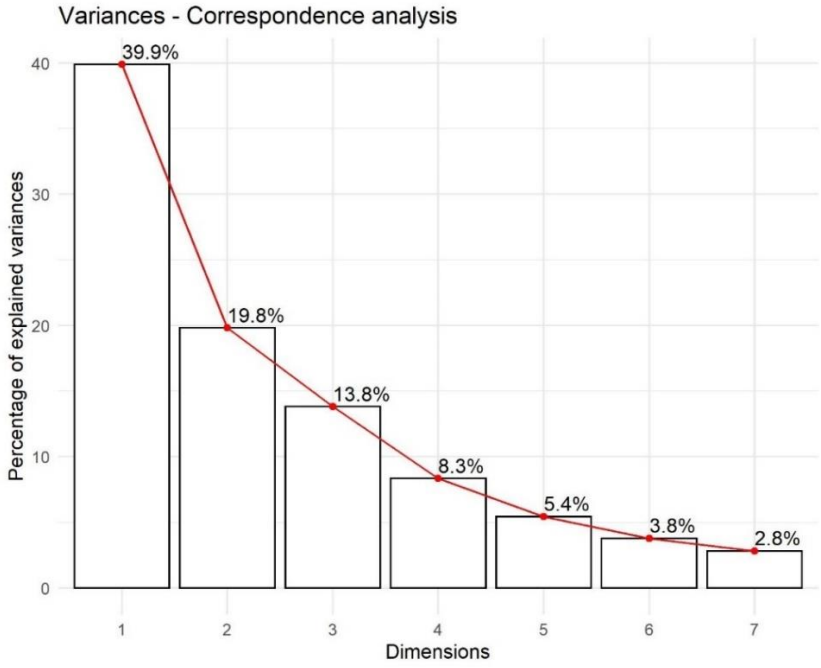


Figure 8 Scree plot of explained variance by dimensions in correspondence analysis

Interpretation of the calculated results is given by interpreting quadrants of the produced biplot and by interpreting rows and columns' contribution to the first four dimensions of CA. Calculated contributions for columns (cultural ecosystem services and disservices) and rows (UGI types) are presented in Table 6 and Table 7 respectively. The biplot was mapped to be symmetrical and easy to understand; however, because of that, distances between variables presented in the biplot were not identical to those resulting from CA. With regard to that, interpretation was based on both the biplot and contribution tables together.

The first dimension of CA clearly separated two opposite perceptions – Forests were perceived as natural and as providers of opportunities for Watching Nature and Hiking, and parks as more human-influenced parts type of UGI in Zagreb based on their relation to the perception of Maintained and somewhat Noisy places. Also, the respondents perceived parks as being holders of Cultural Identity for the city of Zagreb.

Second dimension separated the second opposite perceptions people hold towards different UGI types in the city of Zagreb. Below the *X*-axis there is a large influence of Cultural Identity and Education as cultural ecosystem services, while on the upper side there are perceptions of all disservices, specifically, UGIs perceived as Unmaintained places and those that are perceived as Scary along with recreational activities of Running and Biking.

The Botanical/Zoo garden and parks were perceived as places offering opportunities for Education and as holders of Cultural Identity for the city or city district.

Contrary to the UGI types perceived in relation to Education and Cultural Identity as intangible values of green spaces, there were locations used for everyday recreational activities and perceived as sources of disservices. Those included the perception and activities such as Running, Biking, Dog Walking and places perceived as being Unmaintained, being Scary or those where Conflicts with other users could or did occur.

The category that mostly contributed to the second dimension in general was other as a UGI type, which was perceived as Unmaintained and Scary. However, this type was also perceived as suitable and used for Dog Walking and Biking, even for Running, hence the spatial placement of the other was in-between recreational activities and disservices in the biplot.

Water features also significantly contributed to the second dimension by providing opportunities for Running and Biking, confirmed by the number of collected spatial markers for these services. Greenery around residential buildings as UGI type also contributed to the second dimension by being perceived and used similarly to water features and other UGI types.

The third and fourth dimensions were not presented graphically. The third dimension emphasised the connection between children's playground and chances for conflicts to emerge there. However, the position of playgrounds as a UGI type in a biplot indicates that the respondents placed a small number of markers on these facilities, which is in line with the previous results.

The fourth dimension was highly influenced with opportunities for Education offered by UGI in Zagreb along with the perception of some UGI types being Scary on the one side, and opportunities for Socializing and perception of aesthetically Maintained places that are perceived as Noisy on the other side. Tree alleys were perceived as a Noisy environment, while greenery around business areas and brownfields were perceived as Scary places in this dimension. However, it should be emphasised that since the third and fourth dimensions together explains only 21.1% of variance, the differences were not as emphasized as in the first two dimensions.

Cultural ecosystem service of Place Attachment and UGI type of park forests are located near the intersection of axes, indicating little variation from the average values calculated. Hence the position of park forests between parks as heavily human-influenced part of UGI and forests,

perceived as highly natural environments, reflect their role as a part of UGI in Zagreb. Place Attachment being defined as the 'favourite green space' can be found in many UGI types, hence its placement in the middle of the biplot.

Table 6 Column contribution (explored cultural ecosystem service and disservice attributes) in the first four dimensions of correspondence analysis biplot

CES/Disservice	Dim 1	Dim 2	Dim 3	Dim 4
Place Attachment	0.0457	0.0089	0.0402	2.1286
R/Bike	0.3675	4.7704	0.0184	0.6458
R/Dog	0.5069	4.1258	0.2210	0.0065
R/Hike	60.7055	0.0372	0.0643	3.4231
R/Kids	0.9195	0.7780	0.2374	2.7696
R/Nature Watching	4.9173	0.2611	0.0296	1.2522
R/Run	0.2765	7.2573	0.4995	0.9417
R/Social	0.7265	0.3896	0.0820	6.9769
R/Walk	0.0127	1.0093	0.2003	0.0362
A/Experiences	1.1491	1.6634	0.1625	4.5814
A/Maintained	5.0026	0.1285	0.0151	11.5788
A/Naturalness	11.1570	0.4458	0.0144	0.4759
A/Restorative	1.0413	1.2542	0.0447	0.0016
D/Conflicts	0.1082	4.6371	93.9022	0.5656
D/Noisy	3.6822	0.0660	0.0065	5.5366
D/Scary	0.5494	17.4382	2.1318	11.7683
D/Unmaintained	0.2409	28.2900	2.0968	2.4250
Education	0.0762	10.7279	0.0026	44.0972
Cultural Identity	8.5152	16.7113	0.2310	0.7891

Table 7 Row contributions (UGI types) in the first four dimensions of correspondence analysis biplot

UGI type	Dim 1	Dim 2	Dim 3	Dim 4
Botanical/Zoo Garden	0.5226	19.0915	0.0664	39.6021
Brownfield	0.5916	2.9325	0.6084	2.1598
Cemetery	0.5766	2.7863	0.0000	4.4326
Forest	74.8393	0.0413	0.0555	1.3588
Greenery of Educational Facilities	0.1027	1.2908	0.4005	1.1708
Greenery around Residential Building	0.6009	4.5732	0.8358	2.6379
Institutional Green	0.0920	0.0467	0.1816	0.0824
Nursery	0.2082	0.0273	0.0120	1.6604
Other	0.5803	26.0852	0.6459	3.6641
Park	19.1636	7.2548	0.8703	13.3018
Park Forest	0.3134	1.0529	0.7888	10.3346
Public Green Areas	0.4419	0.1268	0.1896	0.0046
Recreational Facility	0.1692	0.1553	0.1269	0.0689
Sport Field	0.7388	7.7903	1.4906	0.4440
Tree Alley	0.6502	0.7234	0.1351	6.1224
Water Feature	0.0873	13.1452	0.2186	2.0826
Community Garden	0.0153	1.9554	0.3121	4.3146
Greenery around Business Area	0.1936	5.7319	0.9300	5.2965
Dog Park	0.0759	2.0242	0.2071	0.3439
Children’s Playground	0.0367	3.1651	91.9248	0.9173

4.5. Density analysis – Kernel density estimation

The results of the employed Kernel density estimation analysis are the hotspot maps, i.e. cartographic representations of specific places inside AOI where a high number of collected point data was located. Cartographic representations are presented in Figure 9. Darker red colours indicate hotspots, blues on a map represent locations where a low number of spatial markers were placed, while the places where base map is visible represent locations where none of the spatial markers were placed ('coldspots'). A different number of value classes were used for visualization of hotspot maps. Classes varied from 10 for Place Attachment and Naturalness to 4 used for places perceived as Scary.

For Place Attachment multiple hotspots were found, indicating several locations and different types of UGI that respondents perceived as their favourite green spaces. Respondents placed spatial markers throughout the whole city of Zagreb, but spatial markers clustered in the central part of Zagreb, on several locations on Medvednica Mountain, in parks Maksimir, Jarun and Bundek and some park forests (Figure 9).

Recreational activities had various spatial distribution patterns throughout the city of Zagreb. For Dog Walking, Taking the Kids Out, Running, and Watching Nature as the recreational activities, Maksimir Park was found to be a location that could be defined as a hotspot, especially in the case of Watching Nature as a passive recreational activity. Biking, Hiking, Socialising and Walking show more clustered distribution, resulting in several hotspots found in the city of Zagreb. Hiking is naturally located mostly, but not exclusively, at the slopes of Medvednica Mountain, where specific hotspots were found. By visual inspection of locations that were obtained from density analysis as hotspots, it can be seen that locations of hotspots on the west, east and around upper central part correspond with mountain huts and other specific hiking infrastructure.

Density analysis of the collected spatial markers for Socializing resulted in four hotspots located mainly in the city centre or in its vicinity, and highlighted the importance of bigger parks in Zagreb such as Maksimir, Bundek, Jarun and green spaces located in the city centre. Similar patterns were found for Biking, without a hotspot in the city centre, and highlighting three big parks (Maksimir, Bundek and Jarun).

Despite being the most often chosen recreational activity, Walking does not show diversity of hotspot categories. Some locations in Zagreb were found to be more often mapped for Walking than others, such as Maksimir Park, but other than that no additional hotspots were found.

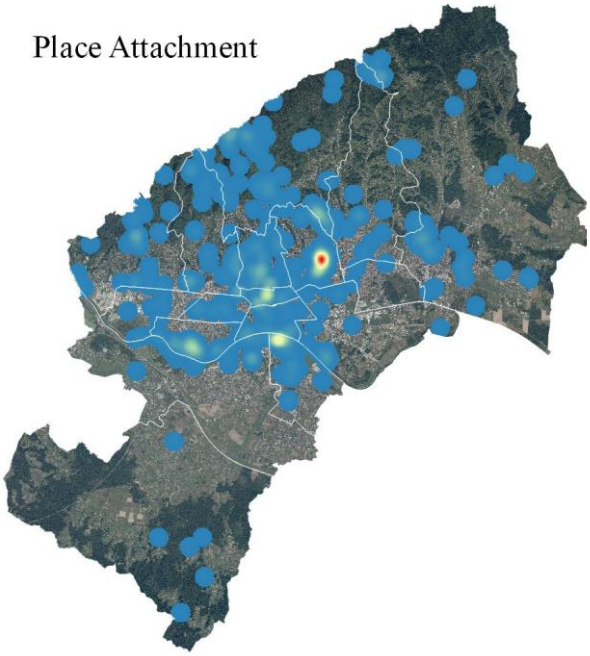
Similar spatial distribution patterns emerged as a result of density analysis employed for all four attributes of Aesthetics as cultural ecosystem service. Perception of locations providing Aesthetic Experience (being beautiful to the respondents) and those being Maintained were mainly related to the mentioned three big parks (Maksimir, Jarun, Bundek) and green spaces (parks and park forests) located in the city centre. Naturalness and locations perceived as Restorative were spatially dispersed, with Naturalness being found on the slopes of Medvednica Mountain, once again highlighting mountain huts as hotspots, but also in park forests, where Dotrščina was highlighted as one of the hotspots alongside Maksimir Park. Restorative locations were found all over the city, but hotspots were located in Maksimir Park, parks and park forests in the city centre, parks Jarun and Bundek and around significant landscape of Savica Lakes– riparian area characterised by 12 lakes and a high diversity of bird species.

As mentioned, a smaller number of spatial markers was collected for attributes of disservices. This is why density analysis resulted in a smaller number of hotspots. The hotspots of perceived disservices were parks Jarun and to a smaller extent Maksimir, but spatial patterns were rather dispersed, and the resulting hotspots should be interpreted with caution. Hotspots of Noisy places were Jarun and Zrinjevac Park, located in the city centre.

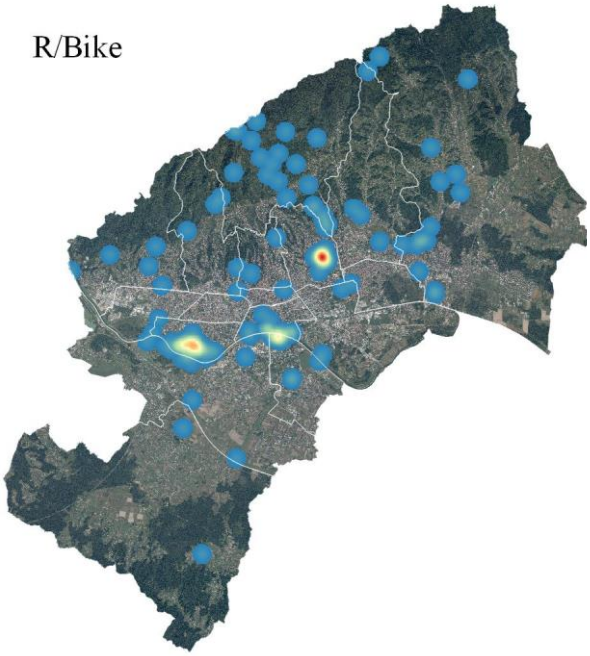
Hotspots for cultural ecosystem service of Education were mainly located in Maksimir Park and the Botanical Garden, followed by parks Bundek and Jarun, Medvednica Mountain and park forests.

Hotspot map of the collected spatial markers for cultural ecosystem service of Cultural Identity revealed that hotspots were found in green spaces (parks and park forests) in the city centre, followed by parks Maksimir, Bundek and Jarun, park forests such as Dotrščina, Grmoščica and others, as well as Medvednica, but to a smaller extent.

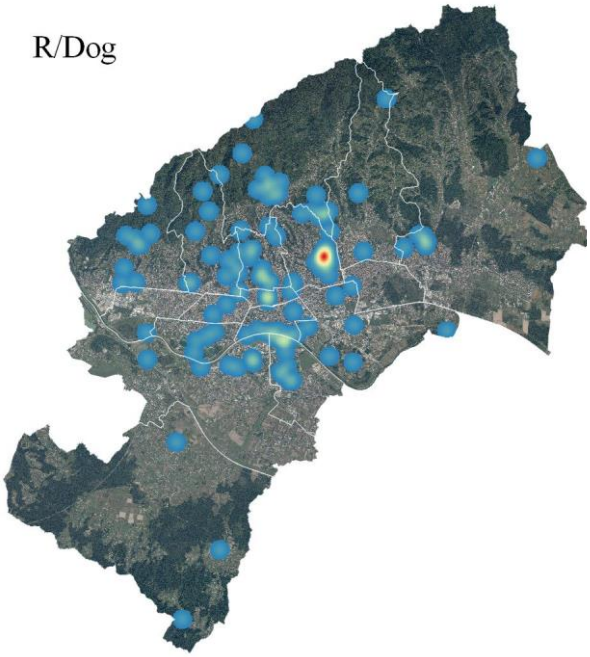
Place Attachment



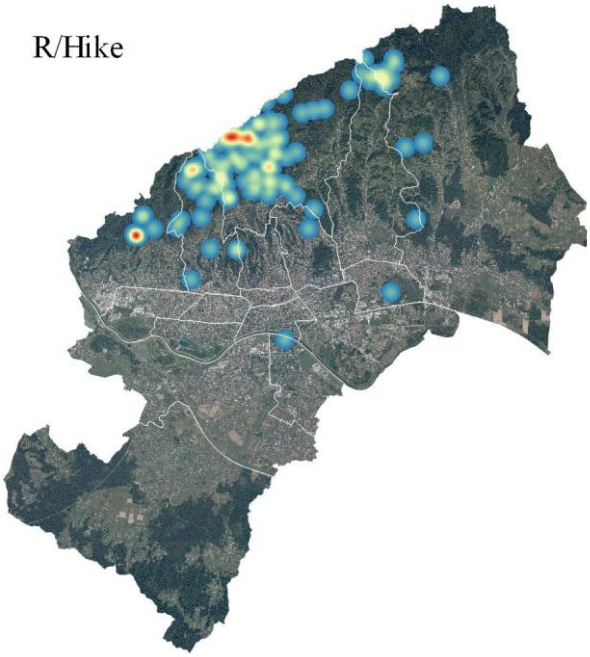
R/Bike



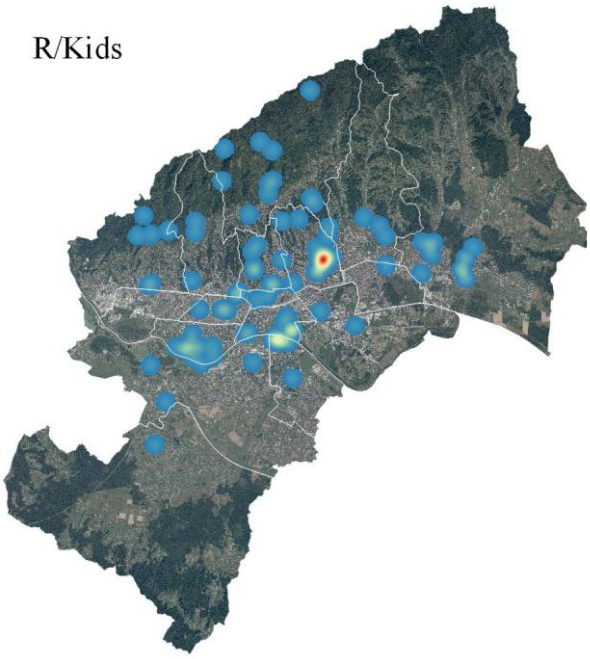
R/Dog



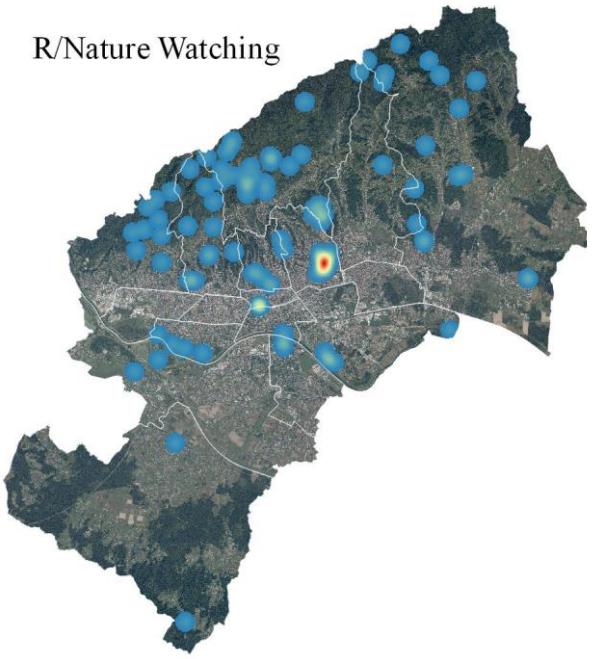
R/Hike



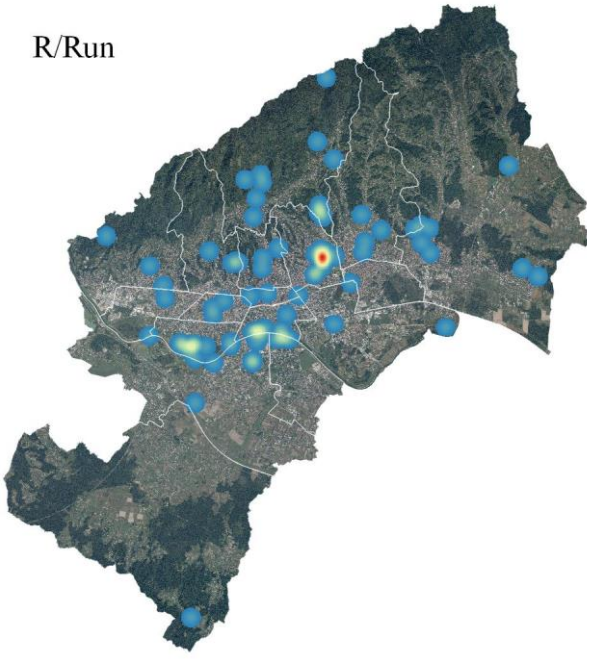
R/Kids



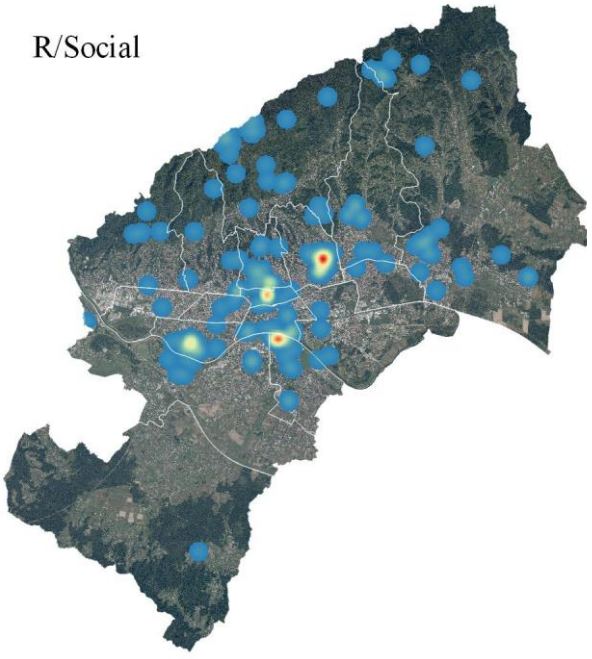
R/Nature Watching

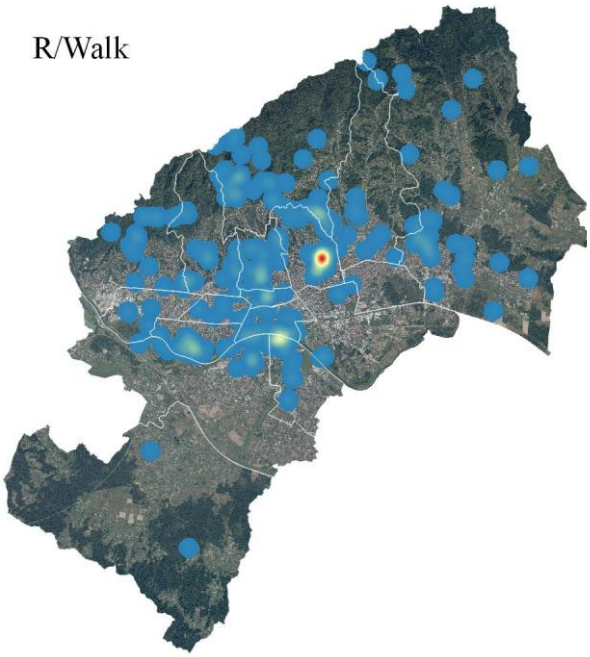


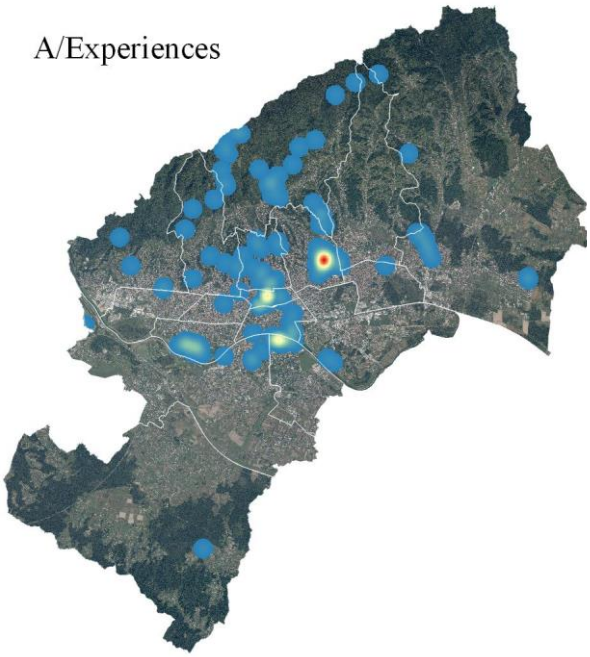
R/Run

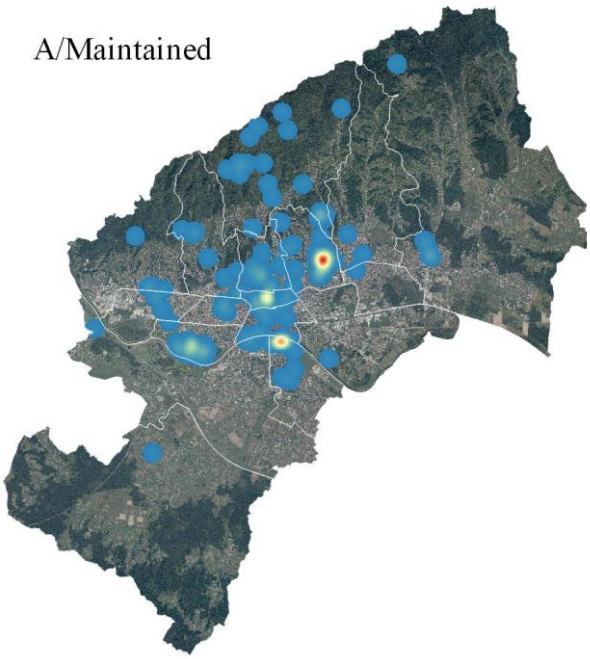


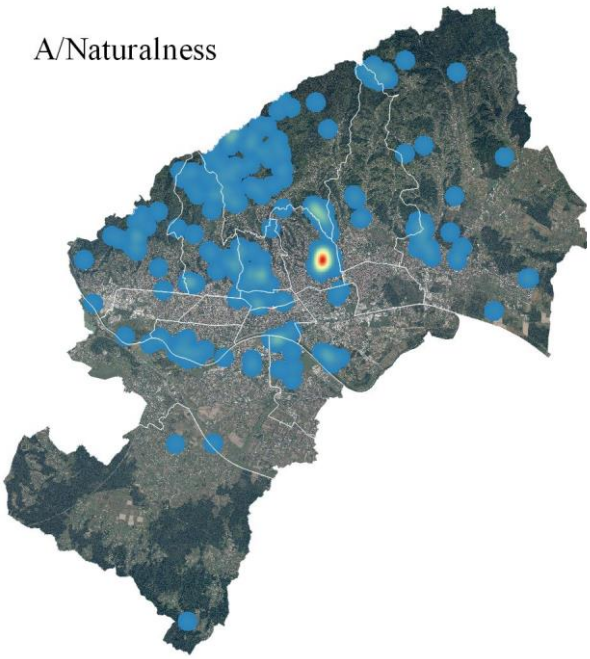
R/Social



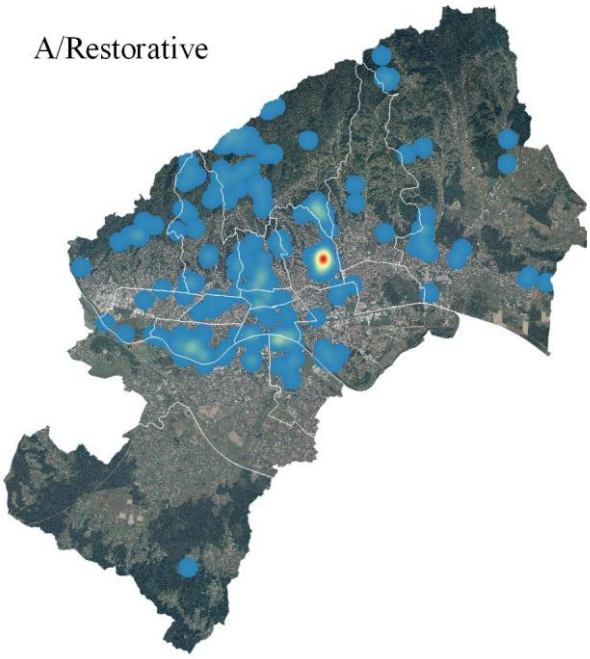

R/Walk


A/Experiences

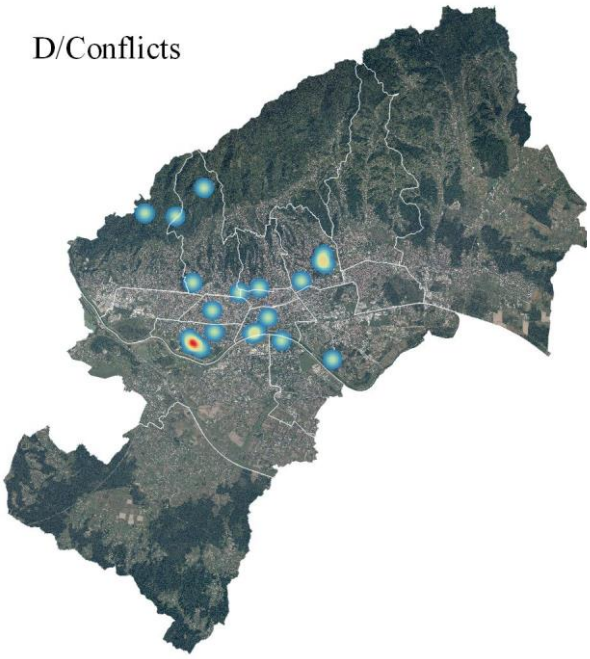

A/Maintained


A/Naturalness

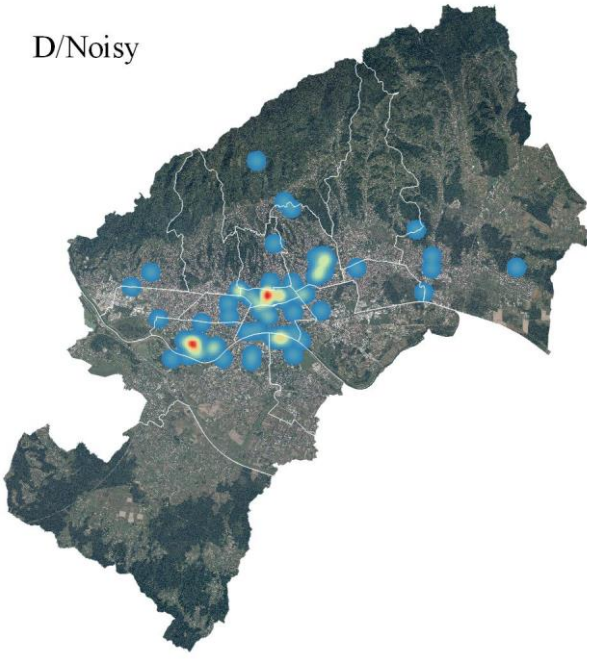
A/Restorative



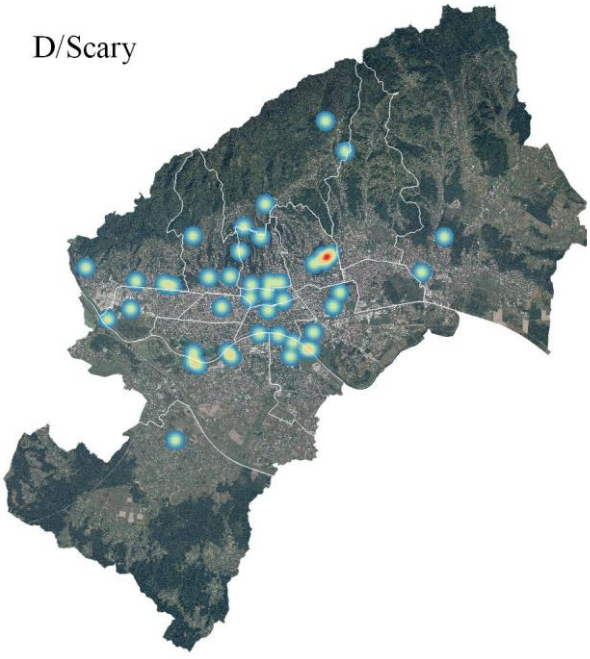
D/Conflicts



D/Noisy



D/Scary



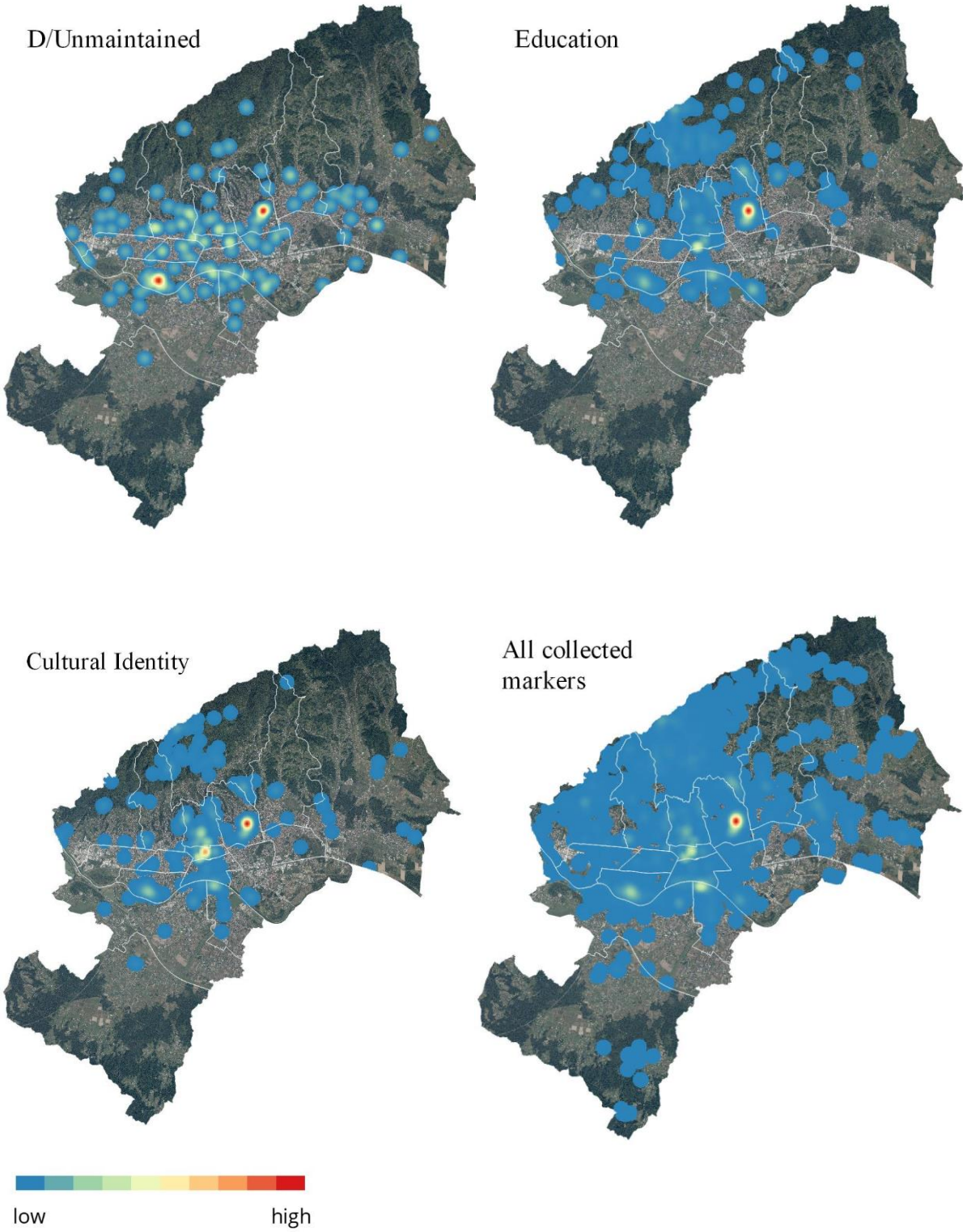


Figure 9 Kernel density estimation results - hotspot maps for each cultural ecosystem service and disservice attribute

4.6. Spatial autocorrelation – Nearest Neighbour Index

The results of density analysis showed visual indication of clustering among the collected spatial markers for explored cultural ecosystem services and disservices. To empirically test whether clustering is statistically significant, or the results of density analyses are just based on parameters chosen for visualisation, the collected spatial data were tested for spatial autocorrelation. The Nearest Neighbour (NN) index was calculated for the collected point data separately for each cultural ecosystem service and disservice category and the explored attributes. Calculating the NN index further explored spatial patterns of the collected markers, to complement previously produced density analysis results and to present a comprehensive overview. The results of this calculation are the values of the observed mean distance between points presented in meters, the expected mean distance between points presented in meters, NN index number, Z-score and the number of points included into calculation.

The results of the nearest neighbour calculations are presented in Table 8. NN index value smaller than 1 indicates that the analysed point distribution shows a trend toward clustering, while index value larger than 1 means that spatial point pattern is dispersed. Z-score is the measure of clustering; the greater negative Z-score, the more clustered the analysed point pattern is. Generally, all collected spatial markers together regardless of their attribute show high clustering throughout the city of Zagreb with low NN index value and Z-score respectively, indicating that there are certain locations in the city of Zagreb that were perceived as hotspots for multiple cultural ecosystem services and disservices, confirming the importance of those places. However, by inspecting each specific cultural ecosystem service category and attribute separately, higher and lower clustering values were found.

The highest clustering values were calculated for Cultural Identity and Place Attachment, with both of them having low NN index (0.27 and 0.32 respectively) and low Z-scores (-40.64 and -39.74). This further support results gathered with density analysis where Cultural Identity showed high spatial clustering, while for Place Attachment several unique hotspots were found. Education and Waking resulted in similar NN index and Z-scores (0.40 and -30.99 for Education and 0.38 and -26.49 for Walking), further supporting the produced maps with density analysis showing more dispersed spatial markers throughout the city but with few highlighted hotspots.

Furthermore, higher clustering values were found for all attributes of aesthetics – Restorative, Naturalness, Experiences, Maintained, and for Socializing as a recreational activity. These are

all attributes with a similar number of spatial points analysed and similarities in produced maps, with density analysis that indicated some level of clustering among spatial markers.

Further supplementing the results of density analysis, other attributes of recreational activities (Biking, Dog Walking, Hiking, Taking the Kids Out, Watching Nature and Running) show smaller clustering values, with both NN index and Z-scores indicating more dispersed point patterns than for Walking and Socializing categories, but with some level of clustering presented.

The results for disservice attributes show the lowest values of clustering. For all four attributes explored, the point pattern showed a trend toward dispersion. Even for the attributes with a similar number of spatial markers collected as some other categories, patterns exhibited lower clustering values (see Unmaintained – N of points 150, NN index = 0.69, Z-score = -7.16 and compare with Biking). For Noisy, similar results from density analysis were found when calculating the NN index, where the highest clustering among disservice attributes emerged (NN index = 0.50, Z-score = -10.20). Places perceived as Scary and locations of Conflicts with other users collected the smallest number of spatial markers that were noticeably dispersed throughout the city of Zagreb, which resulted with the lowest calculated NN index values.

Table 8 Nearest neighbour index (NN) calculated for every cultural ecosystem service and disservice attribute

CES/Disservice	Observed mean distance (m)	Expected mean distance (m)	NN index	N of points	Z-score
All	57.50	209.81	0.27	5,757	-105.37
Place Attachment	159.17	496.45	0.32	935	-39.74
R/Bike	488.62	992.96	0.49	185	-13.22
R/Dog	713.99	1,171.91	0.61	145	-9.00
R/Hike	479.59	760.56	0.63	137	-8.27
R/Kids	482.68	887.42	0.54	139	-10.29
R/Nature Watching	634.83	1,236.56	0.51	138	-10.94
R/Run	706.18	1,368.69	0.52	115	-9.93
R/Social	374.80	865.00	0.43	268	-17.74
R/Walk	234.17	609.13	0.38	506	-26.49
A/Experiences	289.99	846.99	0.34	271	-20.71
A/Maintained	274.27	656.29	0.42	280	-18.63

CES/Disservice	Observed mean distance (m)	Expected mean distance (m)	NN index	N of points	Z-score
A/Naturalness	327.08	790.87	0.41	368	-21.52
A/Restorative	299.08	787.73	0.38	353	-22.29
D/Conflicts	1,081.35	1,162.67	0.93	22	-0.63
D/Noisy	395.72	783.85	0.50	116	-10.20
D/Scary	1,180.65	1,533.16	0.77	45	-2.95
D/Unmaintained	641.11	923.20	0.69	150	-7.16
Education	158.05	393.63	0.40	733	-30.99
Cultural Identity	116.94	430.35	0.27	851	-40.64

4.7. Distance analysis

Descriptive statistics of calculated Euclidean distances are presented in Table 9. As noted, Euclidean distances were calculated for pairs of locations. That is, distances were calculated between the respondent's place of residence represented by centre of a centroid point and every spatial marker placed on the map by the same respondent. Measurements resulted in 5,671 distances. Minimal value measured was below 300 m for all explored attributes of perception except Hiking as a recreational activity. Minimal distances ranged from 21 m for Place Attachment to 814 for Hiking. Maximal values ranged from 9,026 m for places where Conflicts with other people occurred to 29,428 m measured for the Place Attachment marker. Highest mean value was measured for Hiking (9,316 m), while the lowest mean value was measured for perceived disservice of Unmaintained places (2,833 m).

Median values were lower than calculated mean values, but there were also some similarities in measurements. Again, Hiking had the highest median value of 9,419 m and the perception of Unmaintained places the lowest with 1,591 m. Furthermore, cultural ecosystem services with lower median value than 2,000 meters are recreational activities of Dog Walking and Running.

The number of measured distances ranged from 925 for Place Attachment to 22 for perceived locations of Conflicts.

Descriptive statistics presented are further accompanied with boxplot presented in Figure 10, showing median value along with lower and upper quartile values measured for each cultural ecosystem service and disservice explored within this research.

Table 9 Descriptive statistics of calculated Euclidean distances between the location of the respondent's home and cultural ecosystem service and disservice attributes mapped

CES/Disservice	MIN (m)	MAX (m)	MEAN (m)	ST.DEV	MEDIAN (m)	N
Place Attachment	21.12	29,428.23	4,396.32	± 4,095.89	2,996.35	925
R/Bike	32.91	15,815.98	4,108.27	± 3,167.30	3,061.58	182
R/Dog	57.21	14,877.97	2,902.37	± 3,022.04	1,634.71	143
R/Hike	814.47	22,086.50	9,315.99	± 4,274.54	9,419.43	135
R/Kids	53.62	16,932.80	3,628.60	± 3,683.82	2,371.58	138
R/Nature Watching	76.47	20,386.91	5,584.41	± 4,526.26	4,265.93	135
R/Run	87.35	19,246.35	3,008.32	± 3,149.64	1,880.06	115
R/Social	64.86	25,868.07	4,447.39	± 4,106.82	3,120.08	263
R/Walk	77.40	25,934.14	4,229.73	± 4,061.67	2,842.84	499
A/Experiences	101.92	16,028.07	4,515.47	± 3,512.02	3,359.39	268
A/Maintained	78.45	18,023.23	4,126.23	± 3,554.05	2,854.49	275
A/Naturalness	104.92	20,243.70	5,561.85	± 4,212.11	4,587.88	361
A/Restorative	153.25	26,276.34	4,958.95	± 4,169.26	3,468.47	348
D/Conflicts	131.01	9,026.21	3,545.51	± 2,963.98	2,434.79	22
D/Noisy	69.37	23,175.81	3,908.12	± 3,724.92	2,513.55	113
D/Scary	251.58	11,519.72	3,285.69	± 3,162.09	2,071.96	44
D/Unmaintained	108.82	17,052.34	2,832.96	± 3,103.62	1,590.93	147
Education	24.42	25,904.63	5,797.35	± 4,013.34	5,120.79	719
Cultural Identity	42.41	28,115.39	5,424.06	± 4,183.96	4,482.69	839

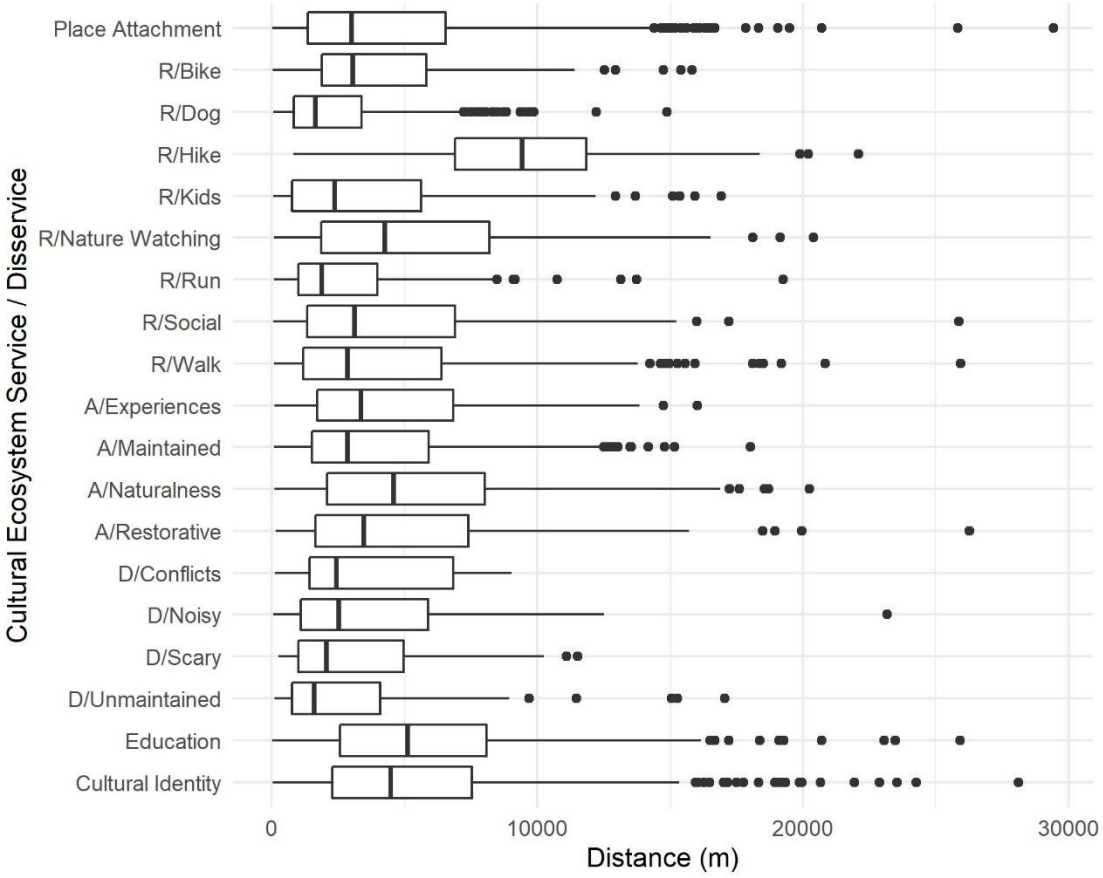


Figure 10 Boxplots showing the range of calculated distances from the respondents' home to every cultural ecosystem service and disservice attribute

4.8. Difference between calculated distances

The Kruskal-Wallis test was used to test the difference between the measured distances of cultural ecosystem services and disservices' perception. The result of the Kruskal-Wallis test showed that statistically significant differences exist between categories of measured distances ($n = 5671$, $df = 18$, $p = 8{,}54 \times 10^{-85}$). Accordingly, based on this result only, it can be concluded that distance from the respondent's home could be used to explain spatial distribution of the collected spatial markers to some extent. Also, attributes of spatial markers when representing one's perception or activity can be explained with distance analysis by providing context to spatially expressed stated preference.

To better understand where the difference between categories emerged, Dunn's post-hoc test after the Kruskal-Wallis test was employed using the Bonferroni correction to produce adjusted *p*-values. Pairwise comparison of distances between categories of cultural ecosystem service

and disservice was calculated. However, only significant results with $p < .01$ are presented in Table 10. The complete table of pairwise results between categories is presented in Appendix 2 of this work.

Out of 171 pairs, 66 pairs of measured distances showed significant differences. The results further highlighted difference between Hiking as a recreational activity and all other explored categories of cultural ecosystem services and disservices, with Hiking having significantly different distance in comparison with all other categories. Education and Cultural Identity categories also significantly differed in distance from the majority of other categories (13 and 10, respectfully). The respondents perceived locations of Education and Cultural Identity as further from home than the locations perceived as favourite indicating Place Attachment. Furthermore, distance from home to locations providing educational opportunities significantly differed from distances for Taking the Kids Out. Unmaintained as a category of perceived disservices apart from having the smallest median value also showed significant differences of measured distances with 13 other explored categories. Distances calculated for Unmaintained did not differ only in relation to other disservice categories (Conflicts, Noisy, Scary), but also recreational activities highlighted as having smaller median values in the previous analysis (Dog Walking, Taking the Kids Out, Running). Place Attachment as a cultural ecosystem service category significantly differed from six categories of Dog Walking, Hiking, Naturalness, Unmaintained, Education, Cultural Identity.

The results of a pairwise comparison between measured distances added to the initial descriptive statistics of measured distances and further enhanced the comprehension of spatial distribution of the collected spatial markers with PPGIS questionnaire.

Table 10 Results of Dunn's post-hoc pairwise test between distances calculated for each pair of cultural ecosystem service and disservice attributes (only significant differences with p < .01 are showed)

Comparison	**Z**	**P.unadj**	**P.adj**
Place Attachment - R/Dog	4.623	0.000	0.001
Place Attachment - R/Hike	-12.295	0.000	0.000
R/Bike - R/Dog	4.076	0.000	0.008
R/Bike - R/Hike	-9.620	0.000	0.000
R/Dog - R/Hike	-12.901	0.000	0.000
R/Dog - R/Nature Watching	-5.984	0.000	0.000

R/Dog - R/Social	-4.162	0.000	0.005
R/Hike - R/Kids	11.214	0.000	0.000
R/Hike - R/Nature Watching	6.820	0.000	0.000
R/Hike - R/Run	11.824	0.000	0.000
R/Hike - R/Social	10.538	0.000	0.000
R/Hike - R/Walk	12.219	0.000	0.000
R/Kids - R/Nature Watching	-4.357	0.000	0.002
R/Nature Watching - R/Run	5.283	0.000	0.000
A/Experiences - R/Dog	5.117	0.000	0.000
A/Experiences - R/Hike	-9.648	0.000	0.000
A/Experiences - R/Run	4.326	0.000	0.003
A/Experiences - D/Unmaintained	5.500	0.000	0.000
A/Experiences - Education	-4.566	0.000	0.001
A/Maintained - R/Hike	-10.920	0.000	0.000
A/Maintained - A/Naturalness	-4.329	0.000	0.003
A/Maintained - D/Unmaintained	4.258	0.000	0.004
A/Maintained - Education	-6.434	0.000	0.000
A/Maintained – Cultural Identity	-4.849	0.000	0.000
A/Naturalness – Place Attachment	5.344	0.000	0.000
A/Naturalness - R/Dog	7.561	0.000	0.000
A/Naturalness - R/Hike	-7.941	0.000	0.000
A/Naturalness - R/Kids	5.559	0.000	0.000
A/Naturalness - R/Run	6.531	0.000	0.000
A/Naturalness - R/Walk	5.562	0.000	0.000
A/Naturalness - D/Noisy	4.198	0.000	0.005
A/Naturalness - D/Unmaintained	7.988	0.000	0.000
A/Restorative - R/Dog	5.847	0.000	0.000
A/Restorative - R/Hike	-9.541	0.000	0.000
A/Restorative - R/Run	4.956	0.000	0.000
A/Restorative - D/Unmaintained	6.255	0.000	0.000
A/Restorative - Education	-4.226	0.000	0.004
D/Conflicts - R/Hike	-5.615	0.000	0.000
D/Noisy - R/Hike	-9.832	0.000	0.000
D/Noisy - Education	-5.556	0.000	0.000
D/Scary - R/Hike	-8.157	0.000	0.000
D/Scary - Education	-4.665	0.000	0.001
D/Unmaintained - Place Attachment	-5.068	0.000	0.000

D/Unmaintained - R/Bike	-4.418	0.000	0.002
D/Unmaintained - R/Hike	-13.277	0.000	0.000
D/Unmaintained - R/Nature Watching	-6.313	0.000	0.000
D/Unmaintained - R/Social	-4.535	0.000	0.001
D/Unmaintained - R/Walk	-4.233	0.000	0.004
D/Unmaintained - Education	-9.846	0.000	0.000
Education - Place Attachment	8.877	0.000	0.000
Education - R/Bike	4.837	0.000	0.000
Education - R/Dog	9.357	0.000	0.000
Education - R/Hike	-7.371	0.000	0.000
Education - R/Kids	7.167	0.000	0.000
Education - R/Run	8.056	0.000	0.000
Education - R/Social	5.888	0.000	0.000
Education - R/Walk	8.479	0.000	0.000
Cultural Identity - Place Attachment	6.756	0.000	0.000
Cultural Identity - R/Dog	8.152	0.000	0.000
Cultural Identity - R/Hike	-8.742	0.000	0.000
Cultural Identity - R/Kids	5.953	0.000	0.000
Cultural Identity - R/Run	6.938	0.000	0.000
Cultural Identity - R/Social	4.317	0.000	0.003
Cultural Identity - R/Walk	6.630	0.000	0.000
Cultural Identity - D/Noisy	4.421	0.000	0.002
Cultural Identity - D/Unmaintained	8.635	0.000	0.000

4.9. Defining urban-rural gradient

Presence of urban-rural gradient in the city of Zagreb was tested by comparing frequencies of the collected spatial markers placed inside UGI of a specific city district in Zagreb. For that purpose, a contingency table of the collected markers representing cultural ecosystem services and disservices was produced for each city district in Zagreb (Appendix 3).

Prior to the analysis, table entries were normalized, and newly created table was used for hierarchical cluster analysis (HCA). Euclidean distance was calculated between variables (city districts), and Ward's agglomerative method was used for clustering.

The results are presented as a cluster dendrogram with six designated clusters. The dendrogram is presented in Figure 11, where specific clusters are isolated with red boxes.

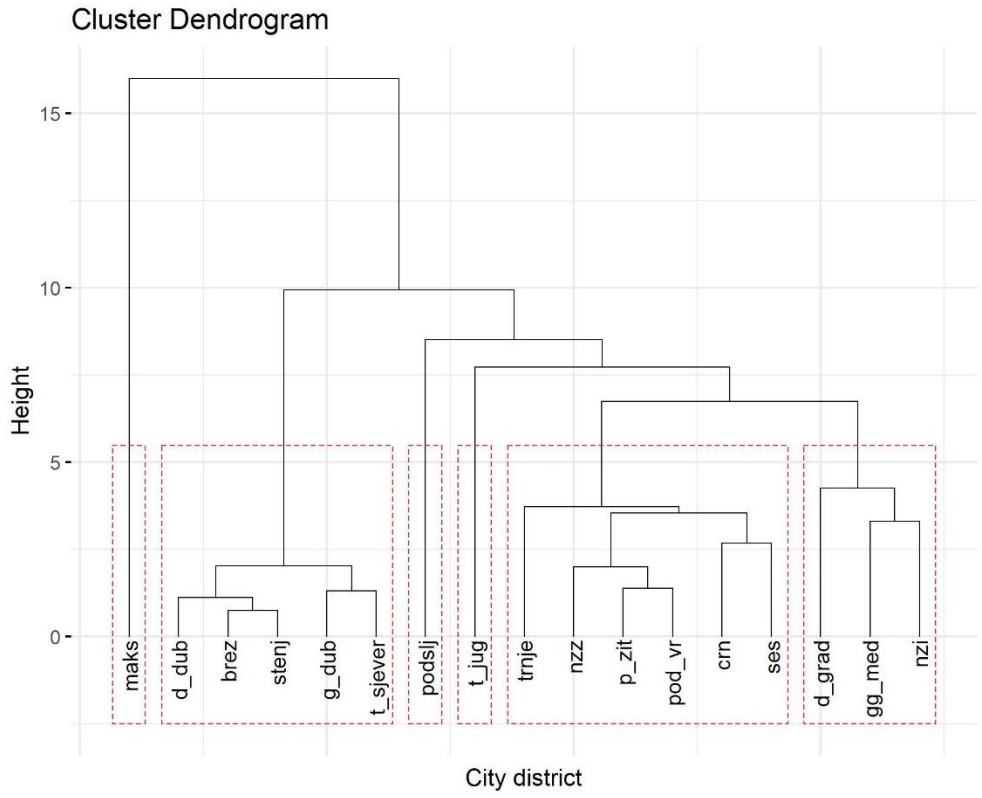


Figure 11 Cluster dendrogram illustrating clustering of city districts of Zagreb based on the respondents' perception of cultural ecosystem services and disservices of UGI in each district

The results of a cluster analysis clearly differentiated Maksimir (maks) as a city district from other city districts in the city of Zagreb. This was due to significance of Maksimir Park as shown in many previous analyses.

The next cluster further divided city districts within Zagreb into clusters of city districts with the smallest number of collected spatial markers and others with more collected spatial markers. City districts with low quantity of collected markers are Brezovica (brez), Stenjevec (stenj), Donja Dubrava (d_dub), Gornja Dubrava (g_dub) and Trešnjevka-sjever (t_sjever). Further, clustering differentiated among those city districts with higher number of collected markers and separated Podsljeme (podslj) as one cluster and Trešnjevka-jug (t_jug) as a second separate cluster.

Final two clusters consisted of groups of similar city districts based on the number and distribution of collected spatial markers. One cluster was formed by the city districts Donji Grad (d_grad), Gornji Grad Medveščak (gg_med) and Novi Zagreb - istok (nzi). The second and the largest one consisted of Trnje (trnje), Črnomerec (crn), Sesvete (ses), Novi Zagreb – zapad (nzz), Peščenica - Žitnjak (p_zit) and Podsused - Vrapče (pod_vr).

To facilitate the interpretation of hierarchical clustering results, cartographic representation of the collected number of spatial markers by city district is presented in Figure 12. The number of spatial markers were aggregated on a city-district level and presented in five categories with natural breaks between them.

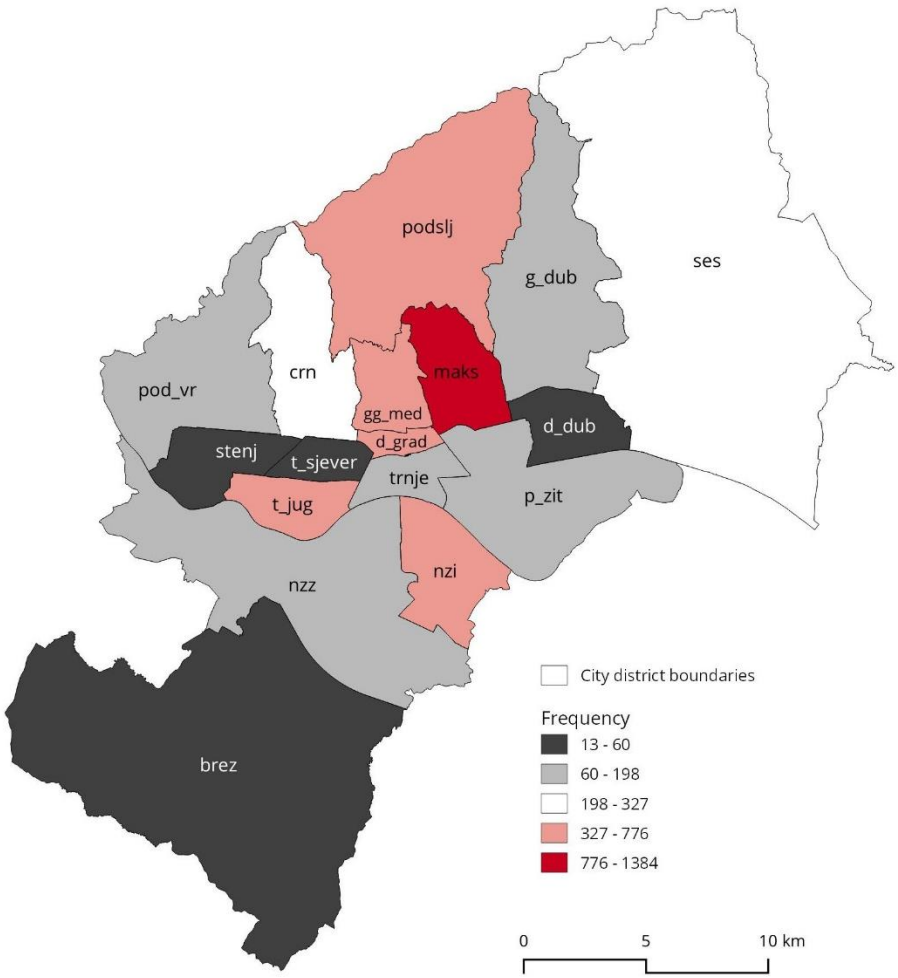


Figure 12 – Cartographic representation of the number of collected spatial markers by city districts in Zagreb presented in five classes

4.10. Socio-demographic characteristics of the sample

In total, 389 people participated in research from start to end.

Out of initial 389 people, two of them stated that they are under the age of 18 and since it was upfront decided to include only people who are 18 years old or older, these two entries were removed from further analyses. Also, since it was decided that the sample includes only citizens of Zagreb, two entries that placed spatial markers of residence outside of the city boundaries were also excluded from further analyses. One entry to the database was a duplicate. The final sample of respondents consisted of 384 people.

None of the questions in the questionnaire were mandatory for the respondents to answer to progress further, hence there are some questions with *nodata* answer, indicating that some people did not respond to a specific question. Socio-demographic profile of the respondents is presented in Table 11.

More women than men (64.6% and 33.6% respectively) participated in the survey.

Mean age for of sample is 38 years old and age ranges from 18 to 67.

The majority of participants hold some of the higher-education degrees, while three quarters of the respondents stated that they had degrees from bachelor to PhD.

Likewise, the majority of respondents stated that they were employed, while further 6.8% were self-employed. There are 7.8% of students in the sample, while the least number of participants are retired.

Household income was explored through statements. The majority of respondents in the sample stated that their household income was enough to cover the basic household needs, 24% stated that it was more than enough to cover the basic household needs and 10.9% stated that their household income was not enough to cover the basic household needs.

The average number of underage children in the household is 0.6, ranging from 0 to 4.

More than half of the respondents stated they did not have a dog in the household.

An average respondent has been living in its city district for 18.6 years, with duration ranging from 0.02 years (only few weeks) to the maximum of 63 years. When asked about living in the city of Zagreb, the average respondent has been living in the city of Zagreb for 30 years, ranging from 0 to the maximum of 66 years (Table 13).

Table 11 Socio-demographic profile of the respondents who participated in MyDynamicCity Zagreb PPGIS questionnaire

	Variable		**%**	**N**
Gender	Female	248	64.6%	384
	Male	129	33.6%	
	I do not want to state	3	0.8%	
	nodata	4	1.0%	
Age (years)	mean (sd)	37.7 ± 10.7		379
	min	18		
	med	37		
	max	67		
Age group	18-30	123	32.0%	384
	31-45	162	42.2%	
	46-60	89	23.2%	
	60+	5	1.3%	
	nodata	5	1.3%	
Level of Education	Elementary school	1	0.3%	384
	High School	83	21.6%	
	Bachelor	61	15.9%	
	Master	167	43.5%	
	PhD	65	16.9%	
	nodata	7	1.8%	
Employment	Student	30	7.8%	384
	Employed	301	78.4%	
	Self Employed	26	6.8%	
	Unemployed	16	4.2%	
	Retired	5	1.3%	
	nodata	6	1.5%	
Household Income	Enough	244	63.5%	384
	Less	42	10.9%	
	More	92	24.0%	
	nodata	6	1.6%	
Number of children in the Household	mean (sd)	0.6 ± 0.9		373
	min	0		
	med	0		
	max	4		

	Variable		%	N
Having a Dog	No	252	65.6%	384
	Yes	124	32.3%	
	nodata	8	2.1%	

4.11. Representativeness of the sample

Representativeness of the collected sample of citizens was determined by comparing socio-demographic data provided by the respondents with the official statistical data from Statistical Yearbook of the City of Zagreb (2021). Where possible, the most recent data from the Yearbook was used. Even though similar gender distribution is present in the city of Zagreb with more female inhabitants, the collected sample is slightly off-balance since it has the higher percentage of females than statistical data (64.6% versus 52.75% for the city of Zagreb).

Overrepresentation of younger age groups (18-30 and 31-45) and underrepresentation of older age group (60+) is present in the collected sample; however, the number of respondents in the age group 46-60 is similar to the proportion of the same age group in the city of Zagreb.

Average age of the citizens of Zagreb is 41.6 years, while in the sample the calculated mean age is rather close (37.7), thus close to the average citizen of Zagreb.

Regarding education of the respondents, they are more educated than the general population in the city of Zagreb, with underrepresentation of respondents in lower education levels than university (elementary and high school).

Based on the official statistical data around 65% of adults (18 years and older) are employed or self-employed, meaning that in the collected sample there are more employed people than in the general population. Likewise, there is again an underrepresentation of retirees in the sample in relation to the general population. The number of respondents stating that they were unemployed is close to the official data (4.2% in the sample versus 3.7% in the city of Zagreb).

Frequency table of respondents participating from every city district was made based on Place of Residence spatial marker (where applicable) or the stated city district from closed-ended question in cases when spatial data about residency quadrant was not provided (Table 12). Table was used in comparison with statistical data provided by the city of Zagreb on the proportional number of inhabitants in each city district to test spatial representativeness of the

sample. Based on a chi-square statistic and the comparison between the number of people in the sample and the proportion of inhabitants within a specific city district, it was concluded that spatially the sample of respondents is not representative for the city of Zagreb. The chi-square statistic resulted in $p > .05$, indicating independence between tested variables.

Table 12 Number of participants engaged with the PPGIS questionnaire from each of city district in Zagreb

City district	PPGIS questionnaire
Brezovica	7
Črnomerec	16
Donja Dubrava	10
Donji Grad	15
Gornja Dubrava	15
Gornji Grad - Medveščak	18
Maksimir	29
Novi Zagreb - istok	31
Novi Zagreb - zapad	29
Peščenica - Žitnjak	28
Podsljeme	10
Podsused Vrapče	19
Sesvete	60
Stenjevec	16
Trešnjevka - jug	23
Trešnjevka - sjever	28
Trnje	25

4.12. Respondents' visiting behaviour towards green spaces in the city of Zagreb

Prior to mapping, the respondents were asked about usual behaviour they express while visiting green spaces in Zagreb in their everyday life. Descriptive statistics on the collected answers and their frequencies are presented in Table 13.

The sample consists of frequent visitors to green spaces in Zagreb, with the majority of respondents who stated visiting green spaces at least once a week or frequently (every 2-3 days or daily). The least number of respondents stated that they seldom visit green spaces in Zagreb.

More than half of the respondents visit green spaces by arriving on foot, followed by using a car and riding a bicycle. Less than 10% of the respondents stated that they use public transport for reaching green spaces and only 1% of them use other means of transportation such as roller-skates.

When asked about the specific part of the day when they use green spaces, two thirds of the respondents declared visiting green spaces in the afternoon, followed by visiting in the morning, and at night, while the least of the respondents stated spending the whole day in green spaces.

When asked about the part of the week when they usually visit green spaces in Zagreb, the respondents stated visiting green spaces throughout the whole week, followed by those who visit on weekends, and the least number of respondents stated visiting green spaces exclusively on weekdays.

Visits for the highest share of the respondents usually last between one and two hours, while somewhat smaller number of respondents stated visits ranging between half an hour and one hour or more than two hours. The least amount of them stated staying up to 30 min while visiting green spaces.

In the end, the respondents were asked with whom they visit green spaces. The majority of the respondents visit green spaces in company of their spouses, friends, or family. The minority of them visit green spaces alone or with kids.

Table 13 The respondents' stated behaviour while visiting green spaces in Zagreb

	Variable		**%**	**N**
Living in city district (years)	mean (sd)	18.6 ± 14.6		376
	min	0.02		
	med	15		
	max	63		
Living in Zagreb (years)	mean (sd)	29.78 ± 14.4		376
	min	0		
	med	30		
	max	66		
Visiting Frequency	Daily	123	32.0%	384
	Every 2-3 days	121	31.5%	
	Once a Week	75	19.5%	
	Every 2-3 weeks	16	4.2%	
	Monthly	19	4.9%	
	Occasionally	23	6.0%	
	Seldom	2	0.5%	
	nodata	5	1.3%	
Mode of Transportation	Bicycle	42	10.9%	384
	Car	78	20.3%	
	Foot	219	57.0%	
	Other	4	1.0%	
	Public transport	29	7.6%	
	nodata	12	3.1%	
Part of the Day	Morning	63	16.4%	384
	Afternoon	261	68.0%	
	At Night	39	10.2%	
	All day	14	3.6%	
	nodata	7	1.8%	
Part of the Week	Weekdays	36	9.4%	384
	Weekends	152	39.6%	
	Whole Week	187	48.7%	
	nodata	9	2.3%	
Duration	Up to 30 min	32	8.3%	384
	30 min to 1h	103	26.8%	
	1h to 2h	161	41.9%	
	More than 2h	81	21.1%	
	nodata	7	1.8%	
Company	Alone	90	23.4%	384

Variable		%	N
With Company	235	61.2%	
With Kids	50	13.0%	
nodata	9	2.3%	

4.13. Correlations between mapped cultural ecosystem services and disservices of urban green infrastructure and socio-demographic or visiting behaviour variables

Correlation matrices are produced to explore the relationship between the number of mapped cultural ecosystem service and disservice attributes and socio-demographic or visiting behaviour variables by the respondents who mapped them. Contingency tables with frequencies of mapped spatial attributes for each group are created for the chosen categorical socio-demographic and visiting behaviour characteristics. Groups of frequencies representing *nodata* values are removed beforehand from the contingency tables. Contingency tables without *nodata* values are further employed for calculating the correlation among variables using Spearman's rank sum correlation.

Correlation matrices produced for socio-demographic variables of Gender, Age group, Level of Education and Employment are presented in Tables 14, 15, 16 and 17.

The chosen variables representing visiting behaviour are Visiting Frequency, Part of the Day, Part of the Week, and Duration. Produced correlation matrices are presented in Tables 18, 19, 20 and 21.

Bolded data in all tables represent statistically significant correlations with $p < .01$.

4.13.1. Correlation between frequencies of mapped attributes and socio-demographic variables

Correlation matrices for socio-demographic variables show high correlation values between the groups of variables, the majority of which are also statistically significant. High and significant correlations are present between genders and age groups.

Correlation matrix of mapped attributes by respondents with different levels of education distinguishes between those with elementary school and other respondents. However, this

correlation is not statistically significant except between respondents with a bachelor's degree where moderate correlation (0.61) is statistically significant with $p < .01$.

Statistically significant correlations are also present between mapped data attributes by respondents with different employment statuses. Moderate and statistically significant correlation was found between retired respondents in relation to other employment statuses, while students even with relatively high and statistically significant correlation indicate differences between mapped points, showing lower correlation values (0.75 to 0.89).

Table 14 Calculated correlation matrix for variable - Gender

	Female	**Male**	**I do not want to state**
Female	1		
Male	**0.94**	1	
I do not want to state	**0.77**	**0.75**	1

Table 15 Calculated correlation matrix for variable - Age Group

	18-30	**31-45**	**46-60**	**60+**
18-30	1			
31-45	**0.89**	1		
46-60	**0.96**	**0.95**	1	
60+	**0.85**	**0.81**	**0.90**	1

Table 16 Calculated correlation matrix for variable - Level of Education

	Elementary	**High School**	**Bachelor**	**Master**	**PhD**
Elementary	1				
High School	0.57	1			
Bachelor	**0.61**	**0.97**	1		
Master	0.55	**0.95**	**0.93**	1	
PhD	0.54	**0.96**	**0.95**	**0.97**	1

Table 17 Calculated correlation matrix for variable - Employment

	Student	**Employed**	**Self-Employed**	**Unemployed**	**Retired**
Student	1				
Employed	**0.89**	1			
Self-Employed	**0.87**	**0.93**	1		
Unemployed	**0.94**	**0.93**	**0.89**	1	
Retired	**0.75**	**0.67**	**0.67**	**0.63**	1

4.13.2. Correlation between frequencies of mapped attributes and visiting behaviour variables

First produced correlation matrix between frequencies of mapped spatial attributes and variables describing respondents' visiting behaviour showed high and statistically significant correlation values among variables (Table 17). An exception are those respondents who visit green spaces seldom. Moderate and significant correlation (no more than 0.65) was obtained between seldom visitors and those who visit daily, occasionally or those visitors that visit green spaces once a week, but none of the significant correlation values were above 0.65.

Correlation matrix for respondents who stated different visiting behaviour with regard to part of the day when they visit green spaces shows a set of high and statistically significant correlation values when looking into the time of the day when respondents visit green spaces (Table 18). The highest correlation was found between those who visit in the afternoon and night visitors (0.94), while the lowest between those who spend the whole day in green spaces and those who visit them at night-time (0.82).

High and statistically significant correlations (above 0.90) were also found between different visiting behaviour based on the part of the week, where all values are above 0.90 (Table 19), and the duration of staying in green spaces (Table 20).

Table 18 Calculated correlation matrix for variable - Visiting Frequency

	Daily	**Every 2-3 days**	**Once a Week**	**Every 2-3 weeks**	**Monthly**	**Occasionally**	**Seldom**
Daily	1						
Every 2-3 days	**0.91**	1					
Once a Week	**0.95**	**0.94**	1				
Every 2-3 weeks	**0.86**	**0.88**	**0.91**	1			
Monthly	**0.88**	**0.94**	**0.93**	**0.59**	1		
Occasionally	**0.88**	**0.87**	**0.94**	**0.87**	**0.92**	1	
Seldom	**0.63**	0.54	**0.65**	**0.94**	0.54	**0.59**	1

Table 19 Calculated correlation matrix for variable - Part of the Day

	Morning	**Afternoon**	**At night**	**All day**
Morning	1			
Afternoon	**0.94**	1		
At night	**0.90**	**0.96**	1	
All day	**0.93**	**0.87**	**0.82**	1

Table 20 Calculated correlation matrix for variable - Part of the Week

	Weekdays	**Weekends**	**Whole Week**
Weekdays	1		
Weekends	**0.96**	1	
Whole Week	**0.93**	**0.92**	1

Table 21 Calculated correlation matrix for variable - Duration

	Up to 30 min	**30 min to 1 h**	**1 h to 2 h**	**More than 2 h**
Up to 30 min	1			
30 min to 1 hour	**0.95**	1		
1 h to 2 h	**0.93**	**0.97**	1	
More than 2 h	**0.92**	**0.94**	**0.95**	1

4.14. Generalized linear models illustrating relationships between frequency of mapped cultural ecosystem service and disservice attributes in relation to respondents' socio-demographic characteristics and stated visiting behaviour

Two sets of generalized linear models (GLM) were produced to enhance the gathered correlation results and further explore whether there is relationship among quantity, attributes of placed spatial markers and main socio-demographic characteristics or visiting behaviour of the respondents. Two sets of GLMs were produced and presented in tables separately by explanatory variables used (one for socio-demographic and one for visiting behaviour variables).

4.14.1. Influence of socio-demographic characteristics of the respondents on the selection and quantity of mapped attributes of cultural ecosystem services and disservices in the PPGIS questionnaire

The entries without placed spatial markers on a map and respondents with *nodata* values in any of the selected variables were excluded from GLMs, resulting in a sample of 371 respondents whose data was used for producing models.

In Table 22 the relationship between spatial markers and the selected socio-demographic variables is presented. The selected socio-demographic variables are Gender, Age Group, Level of Education and Employment. GLM was produced for each cultural ecosystem service and disservice attribute separately. The number of placed spatial markers on the map by each respondent was used as a dependent variable with mentioned socio-demographic variables used as independent variables.

Some independent variables proved to be statistically significant in produced models, indicating the relationship among specific socio-demographic variables and the number of placed spatial markers on the map. It should be emphasised that each respondent had the possibility to put maximum three markers on a map, and therefore the interpretation of the results should be understood with this in mind.

When asked to mark up to three favourite green space (Place Attachment*)* in the city of Zagreb, those with master's or PhD degrees mapped more spatial markers on the map in relation to those having a bachelor's degree.

Being male and unemployed showed to be significant predictor when choosing to place spatial markers representing Biking as recreational activity on a map.

For spatial markers representing locations where the respondents Take the Kids Out, being in the age group 31-45 proved to be influencing and enhancing the possibility of placing this attribute on a map. On the other hand, they were less likely to map green spaces for Hiking or Watching Nature. Holding a master's or a PhD degree proved to be influential and significant for mapping green spaces for Walking.

Being in the age group of 31-45 significantly reduced the number of markers placed for green spaces perceived as places bringing Aesthetical Experience (being beautiful). Those in the age group 46-60 and students were more likely to map Maintained green spaces.

When it comes to green space disservices defined as perceived negativities, those retired or self-employed were statistically significantly more likely to map green spaces where they perceived Conflicts between green space users. On the other hand, those in the age group 31-45 were more likely to map the perceived disservice of lack of green space maintenance (Unmaintained).

Students and those holding a PhD degree were more likely to map green spaces perceived as those providing or potentially providing cultural ecosystem service of Education.

Those with a master's and or a PhD degree were more likely to map green spaces perceived as bearers of Cultural Identity. Furthermore, students and unemployed respondents were more likely to map this particular cultural ecosystem service in relation to the employed respondents.

Table 22 Produced sets of GLMs that model the number of placed markers for each cultural ecosystem service and disservice attribute in relation to the respondents' socio-demographic characteristics

	PA	R/Bike	R/Dog	R/Kids	R/Hike	R/NW	R/Run	R/Soc	R/Wlk	A/Exp	A/Main	A/Nat	A/Res	D/Conf	D/Noisy	D/Scary	D/Unm	EDU	CI
(Intercept)	**0.79*** (0.060)**	**-1.25*** (0.260)**	**-0.961** (0.336)**	**-2.385*** (0.442)**	**-0.93*** (0.246)**	**-0.83** (0.278)**	**-1.47*** (0.327)**	-0.315 (0.181)	0.099 (0.143)	-0.316 (0.161)	**-0.60*** (0.178)**	-0.128 (0.137)	-0.123 (0.136)	**-4.50*** (1.222)**	**-0.83** (0.277)**	**-2.22*** (0.561)**	**-1.74*** (0.340)**	**0.553*** (0.101)**	**0.638*** (0.079)**
Male	0.009 (0.037)	**0.532*** (0.149)**	-0.196 (0.221)	0.230 (0.199)	0.121 (0.158)	-0.202 (0.193)	0.226 (0.200)	-0.071 (0.121)	-0.092 (0.088)	0.188 (0.105)	0.056 (0.109)	-0.058 (0.087)	-0.040 (0.087)	-0.015 (0.475)	-0.351 (0.206)	-0.434 (0.379)	0.002 (0.184)	-0.088 (0.065)	-0.057 (0.050)
Don't want	0.146 (0.222)	-15.809 (1457.08)	-14.123 (1066.1)	-16.022 (2383.79)	-16.689 (2069.9)	-14.672 (889.988)	-14.875 (1418.7)	0.197 (0.662)	0.287 (0.467)	-0.483 (0.823)	-0.282 (0.853)	-0.735 (0.775)	**0.793* (0.390)**	-14.940 (2489.6)	-14.419 (836.11)	1.309 (1.157)	**1.560** (0.553)**	0.386 (0.338)	0.161 (0.279)
31-45	0.020 (0.045)	0.131 (0.188)	0.130 (0.271)	**1.459*** (0.333)**	**-0.549** (0.181)**	**-0.440* (0.217)**	0.198 (0.243)	-0.006 (0.145)	-0.090 (0.105)	**-0.25* (0.124)**	0.236 (0.144)	-0.076 (0.104)	0.056 (0.104)	0.081 (0.551)	-0.427 (0.223)	0.130 (0.399)	**0.572* (0.240)**	-0.026 (0.078)	0.000 (0.060)
46-60	-0.026 (0.053)	-0.061 (0.227)	0.213 (0.305)	0.456 (0.406)	-0.367 (0.215)	-0.407 (0.257)	-0.348 (0.330)	0.003 (0.170)	0.112 (0.118)	-0.240 (0.149)	**0.401* (0.158)**	0.016 (0.119)	0.056 (0.121)	-0.511 (0.756)	**-0.578* (0.277)**	-0.772 (0.588)	0.296 (0.288)	0.069 (0.089)	0.066 (0.069)
60+	-0.054 (0.206)	0.332 (1.008)	1.322 (0.739)	-13.949 (1363.44)	-15.370 (1069.3)	0.237 (0.864)	-15.769 (889.80)	-0.726 (0.767)	0.253 (0.415)	-0.477 (0.816)	0.523 (0.582)	0.088 (0.460)	-0.032 (0.501)	-16.246 (1357.5)	-0.716 (1.202)	-14.046 (1434.75)	0.551 (1.058)	0.228 (0.334)	0.084 (0.251)
Elementary	0.168 (0.382)	0.761 (2542.35)	-0.219 (1855.0)	1.105 (4568.48)	0.321 (3671.1)	0.198 (1574.62)	16.348 (1418.7)	0.811 (0.937)	-14.69 (697.7)	1.493 (1.014)	0.887 (1.209)	0.863 (1.097)	-14.97 (579.2)	2.139 (4319.2)	15.248 (836.11)	-16.393 (3714.26)	-16.123 (2171.87)	-0.246 (0.665)	-0.105 (0.551)
High School	0.037 (0.061)	0.242 (0.252)	-0.233 (0.340)	0.500 (0.388)	-0.417 (0.284)	0.138 (0.285)	-0.495 (0.359)	-0.112 (0.182)	-0.027 (0.147)	-0.204 (0.172)	-0.060 (0.170)	0.144 (0.138)	-0.084 (0.143)	0.446 (1.254)	0.020 (0.288)	0.329 (0.558)	0.331 (0.316)	-0.001 (0.102)	0.011 (0.080)
Master	**0.121* (0.056)**	0.229 (0.239)	-0.139 (0.310)	0.439 (0.347)	0.393 (0.238)	0.130 (0.275)	0.255 (0.297)	-0.002 (0.171)	**0.292* (0.135)**	0.100 (0.154)	-0.060 (0.162)	0.123 (0.131)	0.064 (0.128)	1.856 (1.164)	-0.013 (0.278)	0.171 (0.534)	0.496 (0.300)	0.094 (0.096)	**0.183* (0.075)**
PhD	**0.191** (0.065)**	0.341 (0.272)	0.093 (0.349)	0.457 (0.385)	0.107 (0.290)	0.020 (0.334)	0.070 (0.360)	-0.072 (0.206)	**0.41** (0.152)**	0.099 (0.182)	0.221 (0.179)	0.261 (0.149)	0.242 (0.145)	1.622 (1.244)	0.084 (0.330)	0.168 (0.629)	0.361 (0.345)	**0.287** (0.108)**	**0.303*** (0.085)**
Self-Employed	0.029 (0.069)	0.118 (0.281)	0.450 (0.332)	-0.310 (0.393)	0.509 (0.261)	0.481 (0.306)	0.260 (0.348)	-0.304 (0.261)	-0.062 (0.170)	0.237 (0.187)	0.016 (0.204)	0.013 (0.161)	-0.324 (0.183)	**1.509** (0.541)**	0.279 (0.344)	0.900 (0.460)	0.366 (0.288)	0.020 (0.120)	-0.020 (0.094)

	PA	R/Bike	R/Dog	R/Kids	R/Hike	R/NW	R/Run	R/Soc	R/Wlk	A/Exp	A/Main	A/Nat	A/Res	D/Conf	D/Noisy	D/Scary	D/Unm	EDU	CI
Student	0.124 (0.077)	0.274 (0.323)	0.012 (0.468)	-0.263 (0.738)	0.092 (0.331)	0.109 (0.340)	0.539 (0.416)	0.418 (0.221)	0.295 (0.178)	0.145 (0.210)	**0.515* (0.219)**	0.100 (0.174)	-0.009 (0.185)	0.856 (1.327)	0.197 (0.334)	0.118 (0.685)	0.724 (0.391)	**0.342** (0.124)**	**0.286** (0.099)**
Unemployed	0.074 (0.086)	**0.850** (0.257)**	-0.308 (0.608)	-0.110 (0.474)	0.350 (0.343)	0.493 (0.377)	-0.717 (0.701)	0.231 (0.257)	0.112 (0.199)	0.206 (0.235)	0.271 (0.235)	0.156 (0.194)	-0.149 (0.211)	0.459 (1.060)	0.363 (0.412)	-0.048 (0.821)	0.136 (0.392)	0.151 (0.143)	**0.222* (0.107)**
Retired	-0.187 (0.218)	-15.636 (923.52)	-0.321 (0.932)	-14.583 (1360.39)	-14.254 (1069.0)	-0.846 (1.21)	1.503 (1.05)	0.299 (0.635)	-0.241 (0.490)	-15.52 (753.2)	-0.764 (0.704)	-0.537 (0.529)	-0.713 (0.611)	**3.880** (1.414)**	-0.011 (1.210)	-13.226 (1426.19)	-15.275 (965.386)	-0.686 (0.420)	-0.008 (0.263)
Num.Obs.	371	371	371	371	371	371	371	371	371	371	371	371	371	371	371	371	371	371	371
F	1.331	2.147	0.655	2.854	1.813	0.838	1.114	0.989	1.563	1.270	1.344	0.580	1.458	1.249	1.093	0.817	1.595	2.029	2.239
RMSE	0.61	0.98	1.05	0.97	0.88	0.96	0.89	0.97	0.97	0.91	0.94	0.87	0.86	0.56	0.91	0.74	0.98	0.94	0.79

* $p < .05$, ** $p < .01$, *** $p < .001$

4.14.2. Influence of respondents' visiting behaviour on the selection and quantity of mapped attributes of cultural ecosystem services and disservices in the PPGIS questionnaire

The second set of GLMs produced used the same dependent variables, i.e., the number of placed spatial markers for each cultural ecosystem service and disservice, while as independent variable respondents' visiting behaviour while using green spaces was used. The same procedure of data pre-processing was followed ahead of producing the second set of GLMs. Thus, *nodata* entries as well as the respondents who only answered questions about visiting behaviour without placing spatial markers were removed from this calculation. The produced models are presented in Table 23.

The results showed a smaller number of statistically significant intercepts found in produced GLMs with behaviours as explanatory variables in comparison to models produced with socio-demographic characteristics as explanatory variables. Likewise, a smaller number of statistically significant variables were found in this set of produced models, but some variables proved to influence the distribution of collected spatial markers to a higher degree.

When asked to map their favourite green space (Place Attachment), those who seldom visit green spaces, or never in the previous year, resulted in smaller number of spatial markers placed on the map. Furthermore, those who visit green space on weekends and throughout the whole week placed more markers of this attribute on a map.

Frequent visitors to green spaces (those who visit daily, every 2-3 days and or weekly (at least once a week)) more often placed spatial markers representing green spaces for Biking on the map.

Those respondents who stated that they visited green spaces with their kids were less likely to map green spaces for Dog Walking, but more often placed markers representing Taking the Kids Out as a recreational activity. The respondents who stated visiting green spaces in company of other people more often mapped Walking as a recreational activity.

Those who visit green spaces less frequently (that is, once a month (monthly) or occasionally (defined as several times a year)) were less likely to map green spaces for Hiking on the map.

The respondents who stated that their visits lasted more than two hours were more likely to place a marker indicating Running than those whose visits last between one to two hours in green spaces. On the other hand, those who stated that they spent more than 2 hours in green

spaces were less likely to map a green space for Walking, along with spending time daily in green spaces.

The respondents who stated that they visited green spaces daily, every 2-3 days, once a week and occasionally were less likely to map green space perceived as holders of Aesthetical Experiences than those who visit green spaces every 2-3 weeks. Those respondents who stated that they visited green spaces occasionally put less markers indicating Restorative places.

A more homogeneous sample of respondents' visiting behaviour resulted in models with a smaller number of statistically significant explanatory variables and intercepts. However, some results, even though not statistically significant, revealed that specific variables have little to no influence on a number of spatial markers on the map. For example, Part of the Day when the respondents visit green spaces was not an influential variable for any of the explored cultural ecosystem service or disservice attributes.

The best predictor were respondents' visiting patterns since the quantity of mapped attributes can often be explained with this variable (e.g., Place Attachment, Biking, or Hiking).

Table 23 Produced sets of GLMs that model the number of placed markers for each cultural ecosystem service and disservice attribute in relation to the respondents' visiting behaviour to green spaces in Zagreb

	PA	R/Bike	R/Dog	R/Kids	R/Hike	R/NW	R/Run	R/Soc	R/Wlk	A/Exp	A/Main	A/Nat	A/Rest	D/Conf	D/Nosy	D/Scary	D/Unm	EDU	CI
(Intercept)	**0.764*** (0.117)**	**-2.715* (1.080)**	-1.746 (0.928)	**-2.48*** (0.744)**	-0.893 (0.503)	-0.319 (0.565)	-1.383 (0.722)	-0.386 (0.358)	**0.605* (0.255)**	0.403 (0.309)	-0.667 (0.376)	-0.286 (0.278)	0.262 (0.265)	**-2.994* (1.429)**	-1.018 (0.633)	-2.805 (1.446)	**-1.524* (0.604)**	**0.746*** (0.197)**	**0.899*** (0.155)**
Daily	-0.013 (0.091)	**2.058* (1.037)**	1.459 (0.842)	0.545 (0.593)	-0.166 (0.365)	-0.177 (0.457)	-0.344 (0.568)	-0.313 (0.265)	**-0.503* (0.199)**	**-0.775** (0.236)**	0.291 (0.315)	-0.081 (0.218)	-0.312 (0.206)	0.448 (1.125)	0.109 (0.529)	0.662 (1.173)	0.426 (0.487)	0.034 (0.159)	-0.087 (0.124)
2-3 Days	0.024 (0.090)	**2.184* (1.034)**	0.682 (0.851)	0.325 (0.590)	-0.420 (0.359)	-0.262 (0.452)	0.225 (0.555)	-0.279 (0.260)	-0.299 (0.193)	**-0.519* (0.230)**	0.458 (0.310)	0.099 (0.214)	-0.154 (0.201)	-0.028 (1.144)	0.014 (0.526)	0.780 (1.150)	0.234 (0.482)	0.086 (0.156)	0.026 (0.122)
Once a Week	-0.084 (0.091)	**2.096* (1.034)**	1.055 (0.847)	0.421 (0.586)	-0.525 (0.354)	-0.060 (0.441)	-0.422 (0.585)	-0.456 (0.269)	-0.180 (0.192)	**-0.481* (0.231)**	0.170 (0.315)	0.015 (0.216)	-0.346 (0.204)	-0.325 (1.190)	-0.309 (0.544)	0.158 (1.173)	-0.038 (0.487)	-0.294 (0.160)	-0.143 (0.124)
Monthly	-0.121 (0.116)	1.748 (1.093)	0.400 (1.054)	-0.833 (1.193)	**-1.171* (0.559)**	-0.227 (0.582)	0.254 (0.671)	0.081 (0.318)	-0.157 (0.252)	-0.421 (0.314)	0.440 (0.366)	0.254 (0.259)	-0.399 (0.273)	-16.296 (2223.9)	0.205 (0.629)	-0.522 (1.548)	-0.343 (0.649)	0.108 (0.192)	-0.072 (0.157)
Occasional	-0.197 (0.111)	1.719 (1.078)	0.238 (1.001)	0.899 (0.678)	**-1.160* (0.516)**	0.051 (0.509)	-1.047 (0.888)	-0.500 (0.343)	-0.084 (0.231)	**-0.641* (0.306)**	-0.490 (0.419)	0.129 (0.251)	**-0.539* (0.263)**	-16.211 (1945.0)	0.339 (0.589)	0.108 (1.340)	-0.502 (0.646)	-0.266 (0.195)	-0.198 (0.151)
Seldom	**-1.703** (0.522)**	1.957 (1.455)	1.259 (1.424)	1.187 (1.215)	-0.538 (0.997)	1.204 (0.859)	-13.750 (907.5)	-0.779 (0.932)	-0.175 (0.553)	-0.741 (0.849)	0.453 (0.679)	0.063 (0.580)	-0.110 (0.574)	-16.258 (6595.6)	-16.084 (2331.7)	2.729 (1.408)	-0.149 (1.161)	-0.331 (0.484)	-0.224 (0.358)
Morning	0.054 (0.047)	-0.145 (0.224)	0.175 (0.258)	0.338 (0.233)	-0.263 (0.241)	0.023 (0.239)	-0.490 (0.322)	-0.041 (0.154)	-0.007 (0.113)	-0.064 (0.144)	-0.033 (0.148)	0.169 (0.108)	0.038 (0.114)	0.098 (0.589)	-0.116 (0.253)	-0.505 (0.582)	-0.019 (0.255)	0.077 (0.082)	0.070 (0.065)
At Night	0.032 (0.057)	-0.254 (0.266)	-0.324 (0.358)	0.168 (0.338)	0.104 (0.263)	-0.653 (0.382)	-0.036 (0.305)	-0.130 (0.190)	-0.037 (0.136)	0.015 (0.166)	-0.135 (0.175)	-0.090 (0.139)	-0.057 (0.139)	-0.126 (0.763)	-0.062 (0.299)	-0.118 (0.541)	0.480 (0.250)	-0.068 (0.102)	-0.024 (0.078)
All day	-0.135 (0.106)	-0.591 (0.604)	0.543 (0.445)	0.317 (0.509)	0.179 (0.415)	0.399 (0.424)	-0.933 (0.737)	-0.279 (0.354)	0.091 (0.245)	0.104 (0.278)	-0.033 (0.317)	-0.020 (0.242)	-0.122 (0.253)	0.046 (1.083)	-16.322 (934.07)	-0.286 (1.134)	0.176 (0.503)	0.012 (0.179)	0.063 (0.137)
Weekends	**0.251*** (0.070)**	0.114 (0.285)	-0.054 (0.382)	-0.141 (0.392)	0.341 (0.316)	-0.269 (0.321)	0.244 (0.447)	0.099 (0.230)	-0.175 (0.152)	-0.138 (0.197)	0.024 (0.197)	0.255 (0.169)	0.096 (0.162)	-0.626 (0.801)	-0.303 (0.331)	1.095 (0.835)	0.085 (0.325)	-0.025 (0.112)	-0.021 (0.090)
Whole Week	**0.224*** (0.065)**	-0.020 (0.265)	-0.043 (0.337)	0.050 (0.358)	-0.148 (0.301)	-0.353 (0.301)	0.715 (0.405)	0.262 (0.209)	-0.040 (0.140)	0.085 (0.179)	-0.026 (0.179)	0.303 (0.158)	0.078 (0.149)	-0.223 (0.660)	-0.197 (0.292)	0.656 (0.813)	-0.174 (0.299)	-0.139 (0.102)	-0.008 (0.082)
Up to 30 min	-0.085 (0.068)	0.182 (0.285)	0.183 (0.320)	-0.125 (0.409)	-0.095 (0.343)	-0.032 (0.338)	-0.039 (0.393)	0.157 (0.212)	0.013 (0.155)	0.073 (0.189)	0.193 (0.199)	-0.069 (0.161)	0.060 (0.153)	-0.512 (1.082)	0.322 (0.326)	-1.626 (1.114)	-0.306 (0.405)	0.146 (0.110)	-0.005 (0.091)

	PA	R/Bike	R/Dog	R/Kids	R/Hike	R/NW	R/Run	R/Soc	R/Wlk	A/Exp	A/Main	A/Nat	A/Rest	D/Conf	D/Nosy	D/Scary	D/Unm	EDU	CI
30min to 1h	-0.006 (0.043)	0.079 (0.194)	0.256 (0.236)	0.042 (0.223)	0.096 (0.210)	-0.124 (0.237)	-0.159 (0.249)	0.213 (0.137)	-0.065 (0.101)	-0.043 (0.127)	0.202 (0.129)	0.057 (0.101)	-0.091 (0.104)	0.360 (0.543)	0.210 (0.229)	-0.570 (0.433)	0.164 (0.216)	0.018 (0.074)	0.037 (0.058)
More than 2h	-0.042 (0.047)	0.039 (0.210)	-0.642 (0.342)	-0.105 (0.263)	0.227 (0.210)	0.104 (0.235)	**0.505* (0.244)**	0.149 (0.151)	**-0.286* (0.116)**	-0.063 (0.142)	0.046 (0.147)	-0.015 (0.111)	-0.090 (0.115)	0.826 (0.552)	0.407 (0.245)	-0.498 (0.480)	0.120 (0.236)	-0.118 (0.085)	-0.102 (0.066)
In Company	-0.016 (0.044)	-0.009 (0.189)	-0.259 (0.223)	0.611 (0.339)	0.247 (0.222)	-0.217 (0.219)	-0.234 (0.240)	0.223 (0.144)	**0.233* (0.109)**	-0.181 (0.127)	0.054 (0.131)	-0.045 (0.102)	-0.129 (0.103)	0.291 (0.559)	-0.076 (0.223)	-0.392 (0.407)	0.463 (0.247)	0.030 (0.076)	0.014 (0.060)
With Kids	**-0.150* (0.061)**	-0.480 (0.301)	**-1.12** (0.420)**	**2.264*** (0.332)**	-0.172 (0.315)	-0.888* (0.385)	-0.138 (0.323)	-0.385 (0.228)	0.020 (0.154)	-0.181 (0.177)	-0.223 (0.193)	-0.242 (0.149)	-0.212 (0.146)	-0.009 (0.752)	-0.385 (0.344)	-0.256 (0.552)	0.376 (0.317)	-0.025 (0.105)	**-0.175* (0.086)**
Num.Obs.	368	368	368	368	368	368	368	368	368	368	368	368	368	368	368	368	368	368	368
F	2.616	0.751	2.502	6.735	1.208	0.993	1.682	1.453	1.680	0.945	1.133	0.911	0.790	0.372	0.573	1.039	0.838	1.755	1.435
RMSE	0.58	1.01	0.98	0.89	0.91	0.95	0.91	0.96	0.96	0.92	0.93	0.86	0.87	0.57	0.90	0.73	1.00	0.93	0.80

* $p < .05$, ** $p < .01$, *** $p < .001$

5. DISCUSSION

This work presents the first use of PPGIS questionnaire to assess the perception, use, and spatial distribution of cultural ecosystem services and disservices across diverse types of UGI in the city of Zagreb.

5.1. *MyDynamicCity* Zagreb PPGIS questionnaire

5.1.1. Spatial data quality

Mapping process design employed within PPGIS studies is one of the most important aspects that needs to be addressed properly to ensure internal and external spatial data quality (Brown and Fagerholm, 2015). Based on that, usually while conducting online PPGIS studies researchers do not restrict respondents with the number of spatial markers that they can place on a map (Baumeister et al., 2020; Cusens et al., 2022; Fagerholm et al., 2019, 2016). Explanation for this approach could be that local knowledge is highly valuable and often overlooked while it can provide researchers or policy-makers with important information about the AOI that is usually difficult to collect, hence the respondents should not be restricted with the number of spatial markers (Brown et al., 2012). However, scientific literature also provides an opposite approach where respondents are presented with the limited number of spatial markers that can be placed on a map (De Valck et al., 2016; Ridding et al., 2018; Valánszki et al., 2022). The higher number of markers or attributes available for mapping does not necessary imply more collected spatial data (Brown and Fagerholm, 2015). Within this research, the latter approach was applied, and the respondents were upfront informed about the maximum number of spatial markers that can be placed on a map. The decision to use a limited number of markers per cultural ecosystem service and disservice category was created to make a challenging task of mapping easier for the respondents and to reduce the chance of fatigue. Studies frequently report the low response rate in PPGIS research, and this is not an exclusive issue related to PPGIS questionnaires, but rather an increasingly common phenomenon in all studies using questionnaires as the data collection method (Brown and Kyttä, 2014). Therefore, it is up to the researchers who opt to use a PPGIS questionnaire as a data collection method to design a questionnaire that will fulfil its purpose and collect the necessary data as well as keep the respondents active and interested throughout the process to reduce the drop-out rate. It should also be noted that the respondents in Zagreb were not obligated to place any spatial marker on

the map, either by researcher's instruction or by the application itself, allowing the respondent to choose whether to map or not a certain cultural ecosystem service or disservice indicating the strength of perception and importance. The total number of the collected spatial markers employed for the analyses within this research is 5,757 (Table 4). This number is distributed across the cultural ecosystem services and disservice attributes; also, this large number of collected data indicates high mapping frequency from the respondents, supporting the chosen mapping approach.

Precision and accuracy are indicators of spatial data quality important for PPGIS studies (Brown and Kyttä, 2014). In that regard, the facilitator proved to be beneficial in a similar research, ensuring quality over collected spatial data (Fagerholm et al., 2019). Since there was no facilitator on site with the respondents engaged in this research, complete control over the spatial data was not possible. Mapping errors made by primarily nonexperts are likely to happen and should be expected while conducting the PPGIS research. However, other research showed that data in an aggregate form that is properly prepared should not pose a significant obstacle for analysis and inference (Brown, 2012). For this research, extensive spatial data preparation was done to ensure that high-quality spatial data was used and to analyse only those spatial markers that were directly related to UGI in Zagreb. Possible misplacement of spatial markers by the respondents in data collection phase were not completely avoided, but by excluding those spatial markers that were not placed in any defined UGI type, higher spatial data quality was ensured, subsequently producing more reliable results. Excluded spatial data, comprises only 14% of total number of collected markers, indicating high precision and accuracy from respondents in this research.

The respondents in the PPGIS questionnaire employed for Zagreb were instructed to map green spaces in Zagreb, but at the same time, they were not restricted by application in placing spatial markers anywhere on the map inside or outside administrative city borders. Therefore, the collected spatial data can be used as an indicator of specific strengths and weaknesses of city districts with regard to the UGI present there (Kyttä et al., 2013). Even though the sample of respondents spatially differs from the general population in city districts of Zagreb, unrestricted approach to mapping resulted with maps where one can indicate that some city districts are in deficiency of quality UGI, such as city districts of Trešnjevka - sjever and Donja Dubrava, which will be discussed later.

Since the emphasis of this research was on the citizens of the city of Zagreb and their perception of cultural ecosystem services and disservices, by asking to mark the residence quadrant not only was data about the place of residence collected, but this also ensured that only citizens of Zagreb were included in this research since they were the target population.

5.1.2. Response rate

Because this work is exploratory for the city of Zagreb by trying to apply a new and previously unused type of questionnaire, and collect data about the phenomenon that was not previously explored, non-probability sampling and survey distribution were employed similarly to Rall et al. (2017). The main goal was to attract as many interested respondents as possible and to have a sample of the population that covers the whole city of Zagreb. This goal was achieved since the respondents from all 17 city districts in Zagreb participated in the study.

Due to a combination of non-probabilistic convenience sampling and targeted sampling methods that were used, the response rate could not be reported in percentage as usual. However, through the experience of conducting and distributing the PPGIS questionnaire, lower response rate has been observed. Lower response rates in PPGIS studies have frequently been reported and are usually upfront accepted by researchers (Brown et al., 2014; Garcia et al., 2020; Ives et al., 2017; Jaligot et al., 2019). Following the novelty of approach for the study area, it was not unexpected that potential respondents hesitated to engage with the questionnaire. Furthermore, potential respondents were upfront informed that the questionnaire is employed for scientific purposes only and that the city of Zagreb is not a partner in the research. Considering that the questionnaire was not used to propose changes in land use or to directly enhance green space planning and management, some people were potentially not interested in engaging and allocating their time.

5.2. Results of spatial and non-spatial data analyses

5.2.1. Overview of the analytical approach used

Spatial data analysis followed the analytical framework presented in Fagerholm et al. (2021a). The framework was constructed based on tested, proved, and published PPGIS spatial data analyses and their results. However, it should be mentioned that, as noticed by the authors of the analytical framework, it is still incomplete and could be enhanced with more sophisticated

analytical approaches. For the purpose of this research, the proposed phases of to *Explore* and to *Explain* are sufficient to understand and interpret the results in a meaningful manner. While modelling could be beneficial in terms of predicting where some values are more likely to emerge, more data and a representative sample of population should be collected for modelling results to be operational and meaningful. Nevertheless, employing exploration methods on the collected PPGIS data oftentimes is sufficient to support practical management, while later phases of data analysis are usually developed for the scientific purposes (Fagerholm et al., 2021a).

Spatial weights when analysing spatial data were not used because the scientific literature has shown that weights are of little significance in spatial data analysis (Brown and Fagerholm, 2015). Nevertheless, when presented with unbiased selection of spatial attributes, people use those important to them, thus the number of spatial markers can be used as an indicator of importance among the presented attributes, which will be discussed in detail later.

5.2.2. Usefulness of presented urban green infrastructure classification in Zagreb for exploring the perception of cultural ecosystem services and disservices

The assets of ecosystem services mapping are manifold. The two most important are spatial visualization of ecosystem service provision and defining relations between ecosystem services and spatial indicators (de Groot et al., 2010). The availability of secondary spatial datasets that can be used for analyses is an issue that needs to be addressed. Regularly available datasets include LC and/or LU category, which is then used as an approximation for UGI types (Jaligot et al., 2019; Rall et al., 2017). Land cover, land use and road network data are frequently used as secondary spatial datasets for analysing data collected with PPGIS questionnaires (Fagerholm et al., 2021a). One of the strengths of the presented work in Zagreb is utilizing official spatial datasets gathered from the City of Zagreb for the analyses. These datasets proved to be more detailed and allowed more meaningful analysis that resulted in findings that could potentially be operationalized later. The presented work on merging official data and producing a unique secondary vector dataset employed within this research proved important for capturing the relationship between different cultural ecosystem services, disservices, and UGI in the city of Zagreb.

To provide a complete answer to the first proposed hypothesis that the perception of cultural ecosystem services and disservices is not randomly distributed across the city of Zagreb, but

rather that its distribution is influenced with the type of UGI in Zagreb, the results of multiple analysis should be considered. Combining methods and incorporating integrated assessment approach can produce valid and reliable results (Jaligot et al., 2019). Interpretation of the collected spatial markers' frequencies representing perception with regard to delineated UGI types in Zagreb is supplemented with the results of spatial metrics (Table 5), multivariate analysis (Figure 6 and Table 7), spatial autocorrelation (Table 8), and visual interpretation of produced hotspot maps (Figure 9).

It should be addressed that hotspot maps produced by using Kernel density estimation need to be interpreted along with embracing some methodological limitations, i.e., the bandwidth (search radius used), export pixel size and subjectivity of the mapped data (Alessa et al., 2008). Therefore, when interpreting boundaries presented on a map, one should not use them as actual boundaries of provision and/or perception, but rather as highlighted locations in space that are a guide toward better decision-making. Regardless, density analysis is a useful methodological approach and a communication tool to convey spatial information to professionals in the field and the broader public about the spatial phenomena explored. Also, this is part of the PPGIS data exploration phase that can reveal relationships which could have not been discovered without producing density maps, which was proved important within this work (Alessa et al., 2008; Fagerholm et al., 2021a).

Twenty different UGI types have been defined in Zagreb for the purpose of this research, combining two datasets where the emphasis was put on tree-based UGI in Zagreb. UGI types that were created were further employed to evaluate the relationship between them and cultural ecosystem services and disservices. One of the methods used alongside descriptive statistics was multivariate analysis. Looking at the results of the multivariate analysis it is clear that the differences in perception exists, i.e., that the respondents perceive forests as a UGI type differently than other defined UGI types in Zagreb (Figure 7). Forests are perceived in relation to recreational activities such as Hiking and Watching Nature but are also associated with Naturalness as one of the aesthetic attributes. Coexistence of recreational use and perceptions of aesthetics and naturalness has also been reported before (Beichler, 2015). Here will be highlighted only the most abundant categories of spatial attributes; however, spatial metrics further confirm the importance of forests for diversity of perception and activities establishing them as one of the most important and high quality multifunctional UGI in Zagreb. Hiking can easily be explained with the influence of Medvednica Mountain on the north of the city, with its various hiking trails, being one of the most popular recreational areas for the residents of

Zagreb and tourists alike. Since Zagreb is located at the hills of Medvednica, terrain configuration and forest cover significantly contribute to the respondent's perception. Furthermore, visual analysis of the collected spatial markers revealed that there are three clusters of collected spatial markers for the area of Medvednica. These clusters overlap with the LU category of "Recreational activities in Medvednica Nature Park". Original LU dataset categorizes these areas around mountain huts and the peak of Medvednica. Those are therefore specially managed for recreation and represent visiting infrastructure alongside hiking trails. It is important to mention here that the above-mentioned polygons were reclassified into forest UGI types because of the clarity in the interpretation of the data for the whole city of Zagreb. Nevertheless, polygons remained the same in their geometry and their initial LU category was preserved in attribute table to facilitate the interpretation in the later phases of data analysis. As emphasised earlier, the number of markers representing Naturalness was evenly distributed between parks and forests. However, as it resulted from the CA, forests were more associated with this perception than parks. This further confirms findings from previous studies where forests were also perceived as natural areas on a landscape level (Garcia-Martin et al., 2017), but also as areas of high biodiversity at a city level (Krajter Ostoić et al., 2020a; Rall et al., 2017).

Interpreting further the results of a factor analysis it was concluded that forests and park forests characterise the first dimension in the CA biplot. It should be also emphasised that park forests were located near the middle of the biplot and contribute to a lesser extent to the definition of the first axis. Park forests are forests with different management applied to them in the city of Zagreb. They are managed for recreational purposes, and not for commercial timber production, so more financial resources are allocated towards establishing, maintaining, and upgrading visitor infrastructure such as trails, tables, and benches throughout the forest to promote their use. Based on that, there are differences between park forests and forests in a way that park forests are highly influenced by their recreational potential, which in turn results with these places being more heavily managed and therefore more similar in some respects to parks, but retaining their forest aesthetics, ecological and other benefits. This was confirmed by their placement in the CA biplot in the middle, between parks and forests. Placement in the middle of the biplot near Place Attachment is an indication that there is a connection between park forests and the perception of those places as being favourite to respondents. Park forests are not only managed to provide different benefits to the citizens of Zagreb, but they are also an important part of their everyday landscape since they are located near residential areas. In

relation to forests that are usually located near the city edges, the location of park forests brings certain advantage, but also high pressure from local citizens. Bearing on that, park forests were also perceived in relation to 18 out of 19 explored attributes, confirming their importance for the city of Zagreb by being multifunctional and natural places located near the living areas and indicating their importance on a city level. This is one of the important findings of this work and could be used to enhance urban forest management in Zagreb. There is a link between the perception people hold toward park forests in the city of Zagreb and their main aim. It can be stated, based on the results of this research, that park forests in Zagreb in general successfully fulfil their main purpose. However, it should be noted that this is also a generalization on the UGI type in the city of Zagreb. Some distinct park forests gathered more spatial markers than the others, but more research is needed that specifically focuses on park forests in Zagreb to completely understand to which extent park forests in Zagreb differ between each other.

The Botanical/Zoo garden is the category of UGI that was taken over from the LU dataset (Table 2). The category was not changed because these gardens naturally compose one UGI type. The CA revealed that this type to a great extent defines the second dimension characterised by Cultural Identity, Education, and Aesthetic Experiences. These gardens differentiate from other types of UGI since people need to pay an entrance fee to enter. The Botanical Garden as part of the green horseshoe in the centre of the city is an important not only for botanical and ecological reasons, but also because it represents cultural and architectural heritage in the city of Zagreb. The Zoo as a separate category collected only eight marker points, so it can be concluded that the Botanical Garden is the more important part of this type. Regardless of the entrance fee, these areas are still recognized as important providers of predominantly immaterial cultural ecosystem service.

Maksimir Park emerged as the most often mapped location in Zagreb within this research. Quantity of the spatial markers collected emphasise the importance and quality of Maksimir Park for the citizens of Zagreb. Maksimir is one of the oldest parks in this part of Europe and represents important cultural heritage in the context of Southeast Europe. Since the perception of cultural ecosystem services is quite influenced with, among others, cultural background of the respondents, it was expected that this will also be spatially expressed through mapping exercise. Because of the novelty of this research approach, bias toward mapping collectively well-known places or those that the respondents are familiar with could have emerged. However, even if this was the case within this research, the quantity of mapped data for specific locations provide the stakeholders with essential information about the most important places

in the city of Zagreb. Aside Maksimir, other parks also emerged with high mapping frequency throughout the city of Zagreb, resulting with the highest mapping frequency between UGI types in Zagreb. Parks were recognized as the providers of mainly immaterial cultural ecosystem services, but also some disservices in the city of Zagreb. These results indicate the importance of parks for the city of Zagreb and these findings are also in line with other research that emphasises their importance for the residents in different cities throughout Europe (Chiesura, 2004; Pietrzyk-Kaszyńska et al., 2017; Rall et al., 2017).

One specific UGI type in the city of Zagreb emerged with having the highest diversity of cultural ecosystem services and disservices mapped, and that is other. Other category was adopted from the official LU dataset in the same form as it is presented there. By its definition other areas are "Agricultural areas, Unmaintained areas, Protective Green and Other", hence not probably the exclusively tree-based UGI, but the presence of trees even though not managed cannot be excluded. They emerged as acknowledged on the city level, and this is important especially since these areas are usually under the higher pressure of new construction in the city. The diversity of services in, as they are sometimes called, informal green spaces in the city emerged with similar perception and use in other studies as well (Pietrzyk-Kaszyńska et al., 2017; Rupprecht et al., 2015). Therefore, for the city of Zagreb, these locations are important cultural ecosystem services and disservices provision areas, and future research would benefit from further exploring this relationship. More about the specificity of the interrelationship between other UGI type and its perception and use will be given later in this discussion.

Although the presented classification of UGI in the city of Zagreb could be considered as relatively accurate and detailed, some aspects of classification still need to be considered when interpreting the results. While developing a method that allows a systemic and meaningful merging of two datasets and repeating the same procedure for different cities, some trade-offs occurred. The UGI type of water feature was represented with reclassifying polygons of two water-related categories in the original LU dataset from the city of Zagreb. The first one represents physical water bodies, e.g., the Sava River, water streams, and lakes in the city of Zagreb, and the second one represents water-related infrastructure, such as embankment. The visual analysis of the collected spatial data revealed that some people placed spatial markers near the water bodies (indicating the existence of the trails on embankment), while other people placed markers on a water body itself. Since it is difficult to distinguish between intentions of the respondents when placing the spatial markers on distinct parts of the water-related

infrastructure, only one category was developed. Trade-offs can also be observed in the case of Savica Lakes. Density maps of the collected spatial markers revealed the importance of Savica Lakes located in the southeast part of Zagreb. This is a protected area and an ornithological reserve in Zagreb consisting of 12 lakes and the surrounding landscape. However, the LU dataset does not contain information on the protected areas in Zagreb, so Savica Lakes, along with other protected areas such as Medvednica Nature Park, are not represented in this manner. Savica Lakes are therefore represented with categories of water bodies and other since the surrounding landscape is defined as other in the original LU dataset. While it could be beneficial to include borders of protected areas in the newly created dataset to gather more precise information on underlying geometry and subsequently on management applied, due to a large number and diversity of protected areas in Zagreb it would present an unnecessarily complicated classification and interpretation of results. Nevertheless, the importance of Savica Lakes has been noticed, proving the importance and usefulness of density maps and visual interpretation in the PPGIS research.

The dataset was also built to highlight mostly tree-based UGI in Zagreb, which can be observed in the process of building spatial datasets. Trees are an important building part of UGI in cities, and therefore their importance was highlighted. The presented classification proved as a useful secondary spatial dataset that allowed meaningful interpretation of the gathered results. In the next chapter, the relationship between different aspects of cultural ecosystem service and disservice perception and underlying UGI types will be given in more detail.

5.2.3. Perception of cultural ecosystem services and disservices in the city of Zagreb

Similarities in the perception towards cultural ecosystem services among Western and Central-Eastern European countries (based on an empirical study conducted in Hungary) exist, but specific differences have also been observed (Valánszki et al., 2022). Differences are influenced to some degree by the respondents' historical and cultural background, affecting the perception of specific places (ibid.). Regardless of the methodological approach used, assessments of cultural ecosystem services are still scarce in Eastern European countries, and thus more research is needed in those countries to enhance the current knowledge with empirical research. Based on the aforementioned, scarcity of literature limits the comparison within the local Eastern European context; therefore, comparison will also be given with similar research from Western European, Central European, North American countries and

Australia throughout the discussion. When possible, special attention will be placed on the results from comparable spatial and cultural backgrounds to contribute towards broadening the knowledge of perception of cultural ecosystem services and disservices in the context of Eastern Europe.

5.2.4. Perception of Place Attachment in the city of Zagreb

Place Attachment is a concept often related to one's favourite (green) spaces, therefore the mapping exercise in the PPGIS questionnaire started with mapping those places which respondents perceive as their favourite. The rationale behind starting with mapping favourite places is an assumption that people have their favourite green spaces in the city which they can easily find on a map and put a spatial marker on. Research has shown relatively temporal stability in choosing one's favourite green spaces in the city, especially when the chosen locations are near the water or are located in forested areas (Korpela et al., 2009). Furthermore, favourite green spaces located in the proximity to one's home are important for balancing hectic urban lifestyle, thus improving health and well-being of citizens (Bijker and Sijtsma, 2017). The respondents in Zagreb usually did not have a problem with mapping their favourite urban green spaces in the city, with 370 respondents successfully fulfilling the assignment. Cartographic representation of the collected spatial markers indicates a rather dispersed pattern of collected spatial markers. However, spatial autocorrelation calculation resulted with one of the highest clustering results. Explanation for this, at first, contradictory result is that even though diversity of locations was mapped, few distinctive hotspots could be distinguished from the cartographic representation, indicating greater mapping frequency in those locations. Greater mapping frequency on a small area decreases the distance between the points, hence with several such locations across the city clustering value emerged as high. However, it is also important to emphasise those locations that are not part of the clusters because they are of importance and use for the citizens of Zagreb. Hotspots that emerged are probably a combination of used and favoured UGI in Zagreb since the measured distances range from 20 to almost 30,000 m. Median value, however, is at ~3,000 m, indicating possibly greater influence of accessibility and appropriateness of marked locations for everyday use.

Probably a better indicator of Place Attachment and perception of favourite UGI in the city of Zagreb are the results of CA. Biplot resulted with Place Attachment being placed in the middle of the biplot near the park forests as a UGI type in Zagreb. However, in total markers for Place

Attachment were mapped in 16 different UGI types in Zagreb. From this, it can be concluded that the perception of Place Attachment is specific and is a foundation for the perception and use of other cultural ecosystem services and disservices. This is in line with previous results of qualitative research on the topic of cultural ecosystem services in Zagreb, where Place Attachment was expressed in relation to every defined tree-based urban green space. Based on focus group results, positive memories and perception of locations having utilitarian character were the most often expressed in relation to people's favourite places (Krajter Ostoić et al., 2020a). Furthermore, people often express different reasoning for their favourite green spaces, ranging from appreciating quietness to meeting people (Bijker and Sijtsma, 2017). Regarding UGI types that the respondents mentioned as favourite, parks predominate, followed by forests, park forests, other and water features. It should be emphasised that water features had the highest frequency of mapped markers within this cultural ecosystem service. Indeed, the presence of water bodies alongside the feeling of openness, naturalness, and accessibility shaped the perception of citizens of Zagreb in relation to walking paths around the streams (Krajter Ostoić et al., 2020a). Therefore, it can be concluded that Place Attachment as a cultural ecosystem service is a heterogeneous category, but highly important in shaping human-environment relationship toward meaningful interactions between them that can and should be used further in planning and management (Riechers et al., 2016).

5.2.5. Different recreational use of urban green infrastructure in the city of Zagreb

Recreation is immensely important for health and well-being of people. Besides, recreation proved to be one of the most influential reasons for visiting green spaces, not only in Zagreb (Kičić et al., 2020; Krajter Ostoić et al., 2020a), but also in other European cities (Buchel and Frantzeskaki, 2015; Fagerholm et al., 2021b; Riechers et al., 2016; Vierikko et al., 2020). Recreation as a cultural ecosystem service further stimulates interaction with UGI and therefore allows more cultural ecosystem services and disservices to be perceived. However, recreation as a term is rather ambiguous. Recreation is one of the most easily perceived cultural ecosystem services for respondents, hence it is one of the most explored services, both qualitatively and quantitatively (Cheng et al., 2019). Based on that, it was decided to offer participants multiple recreational activities which they can map. The reason was that the frequency of mapping would indicate the relative city-wide importance of each of the presented activities and that further analyses would possibly differentiate among them and UGI types perceived as

appropriate for each activity. This would subsequently improve our understanding of recreation as a cultural ecosystem service as well as its perception and use.

Walking emerged as the most important recreational activity city-wide. This is in line with the results from previous qualitative analysis where walking was the most popular activity among the respondents and was practiced in different types of green spaces (Krajter Ostoić et al., 2020a). Likewise, Walking was mapped in more than half of the defined UGI types in Zagreb. The highest number of spatial markers was placed in parks, forests, and park forests. Walking is also universally the most common recreational activity in forests and park forests (Gerstenberg et al., 2020; Korpilo et al., 2018; Larondelle and Haase, 2017; Roovers et al., 2002), but also in parks (Brown et al., 2014; Zwierzchowska et al., 2018). Walking has numerous health benefits and moderate pace walking resulted with highest community health benefits in a PPGIS study employed in Australia (Brown et al., 2014). However, walkers in urban forests tend to leave formal trails which could pose a management problem (Korpilo et al., 2018). When it comes to park forests in the city of Zagreb this is an important result because they emerged as providers of this important recreational activity. However, people's presence in any forest can have negative impact on an overall biocenosis (Ciesielski and Stereńczak, 2018). Therefore, with carefully planned network of trails throughout the park forests and forests, health benefits for people would be enhanced, while the stability of the forest ecosystems would be preserved.

Watching Nature as a recreational activity emerged from focus group interviews in a form of observing nature through widow view, but it was assumed that other activities were also related to watching nature, but were not expressed in discussion (Krajter Ostoić et al., 2020a). To assess this assumption, the attribute of recreation related to observing nature (Watching Nature) was offered to the participants in the PPGIS questionnaire. It was used by 114 respondents who mapped it 138 times. Further analysis showed how Watching Nature is highly connected with forests as a UGI type, Hiking as recreational activity and the perception of Naturalness as an attribute of aesthetics. These three attributes further influenced one side of the CA biplot; therefore, it can be affirmed that watching nature is related to recreational activities and that is also used as one. Watching Nature was mapped mostly in forests and parks, while other types of UGI collected significantly lower number of spatial markers representing this activity. Among parks, Maksimir emerged as a highly important hotspot. Since Maksimir Park is a forest-dominated park area, the hotspot result is legitimate and in line with forests being highly

mapped in this context (Figure 13). Furthermore, research has shown that the proportion of natural areas influences the recreational use of urban forests (Gerstenberg et al., 2020).

Figure 13 - View from the Fifth Lake in Maksimir Park onto Medvednica Mountain

The attribute of Hiking as a recreational activity was offered to the respondents to assess to what extent people engage with this recreational activity in Zagreb and to explore where. As expected, the majority of spatial markers were placed on the slopes of Medvednica Mountain. Naturally, hiking occurs on hilly terrains and similar pattern was observed in Madrid region (García-Díez et al., 2020). Since the categorization of UGI did not consider the category of protection, but rather focused on LU types and vegetative features, Hiking is highly connected with forests as the main feature of a Nature Park. Around one third of the respondents hike. Possibly the most important result related to hiking and PPGIS mapping is the precision of placed spatial markers. The respondents were instructed to be as precise as possible, but the level of precision was not defined. However, when it comes to Hiking, the respondents mostly precisely marked mountain huts as probably their final destination when hiking or other important hiking infrastructure. As mentioned earlier, hotspots spatially coincide with the LU category of "Recreation in Medvednica Nature Park", meaning that the results of mapping could be treated as valid and that these LU categories could be further used to enhance the management of forests and hikers within the Nature Park. Since this is a city-wide exploratory study, more detailed analysis of placed marker points in relation to other locations and their characteristics is not a part of this study, but a more detailed, only nature park-oriented study,

could emerge with important results for enhancing the planning and management similar to already existing ones in Europe (Cusens et al., 2022).

Socialising was defined as a recreational activity since urban green spaces are often used for socializing and as meeting points with other people (Kičić et al., 2020; Rall et al., 2017; Vierikko et al., 2020). Social relations were interlinked with mobility-based recreation expressed by respondents themselves when asked about the motivation for using parks (Vierikko et al., 2020), so it was logical to combine these services in a mapping exercise. Also, social relations are one of the existing cultural ecosystem services defined by the MEA (2005). According to literature, parks provide more opportunities for socializing than natural resource areas in Australia (Brown et al., 2014). Based on a study conducted in different European cities, the need for socializing is equally likely to be perceived and used in different spatial and cultural contexts, showing how socializing in green spaces is universal (Bertram and Rehdanz, 2015; Vierikko et al., 2020; Zwierzchowska et al., 2018). Also, having easily accessible green space is beneficial for socializing purposes, especially in cities where people live in single household apartments, and in so doing positively influencing mental health of citizens (Riechers et al., 2016). Socializing was the second most mapped attribute of recreation for the city of Zagreb. More than 200 participants placed markers for Socializing on the map, which indicates the importance of social activities for the respondents and as cultural ecosystem service in Zagreb as well. In the CA biplot, Socializing was placed near the middle, indicating that socializing can be done almost anywhere. In this regard, spatial markers for Socializing were placed in 17 different UGI types in Zagreb, further confirming the previous statement. However, 60% of all spatial markers were placed in parks, also confirming the results of previously mentioned studies, with parks providing socializing opportunities. Hotspot analysis emphasized three major parks in Zagreb that are highly used for socializing purposes, which could be due to their size, but also additional facilities such as coffee shops, benches, trails, and other infrastructure that serve as catalysts for socializing. Forests were also mapped, but to a lesser extent, which may be due to forests being more related to introspection rather than socializing.

Biking, Running, Dog Walking, and Taking the Kids Out emerged with similar spatial distribution and collected a similar number of spatial markers in the city of Zagreb. Spatial patterns of the collected markers with these attributes are more dispersed throughout Zagreb, along with all these activities showing lower median values for distance from the respondent's home. Dispersed spatial distribution of the collected markers was also found for the city of

Berlin in a similar study where the activities of walking a dog and spending time with children were more dispersed than other recreational activities (Rall et al., 2017). Calculated median distances for Dog Walking and Running are below 2,000 m, indicating that the majority of visits to UGI in Zagreb with the aim of running or walking a dog take place near one's home. Similarly short distances have been observed in Belgium, in a larger area of Antwerp province where median distances for these activities were also under 2,000 m (De Valck et al., 2016) and across Sweden (Lehto et al., 2022). The explanation for such specific behaviour may be, like in an aforementioned study, that these are usually routine-based activities during which the respondents are looking for a convenient location rather the exceptional one. To underpin this statement, the results from the CA showed that, for example, the recreational activity of Running is connected with UGI types of other and water features, which are usually flat and close to one's home, but without specific infrastructure, hence suitable for distance running. Similar placement in a biplot has also been found for Biking.

Biking in the case of Zagreb, just like in the Antwerp study, resulted with higher median values for distances crossed for this activity. Spatial hotspots that emerged from placing spatial markers for biking clearly highlighted three big parks in the city of Zagreb (Maksimir, Jarun, Bundek). The reason behind such pattern could be the existence of cycling trails that ensure safe bike riding (Figure 14 shows a biking line in Bundek Park). This could be an important finding for planning and management of green spaces in Zagreb, especially if the aim is to enhance the use of bikes in the city. Since the decision was to use points for mapping in the PPGIS questionnaire, trade-offs that occurred with spatial accuracy were accepted beforehand, hence the specific routes used for biking were not explored in detail like in the research by Korpilo et al. (2018) and Gerstenberg et al. (2020). Nevertheless, even this data present valuable input and foundation for improving communication and planning of new biking routes for the city of Zagreb.

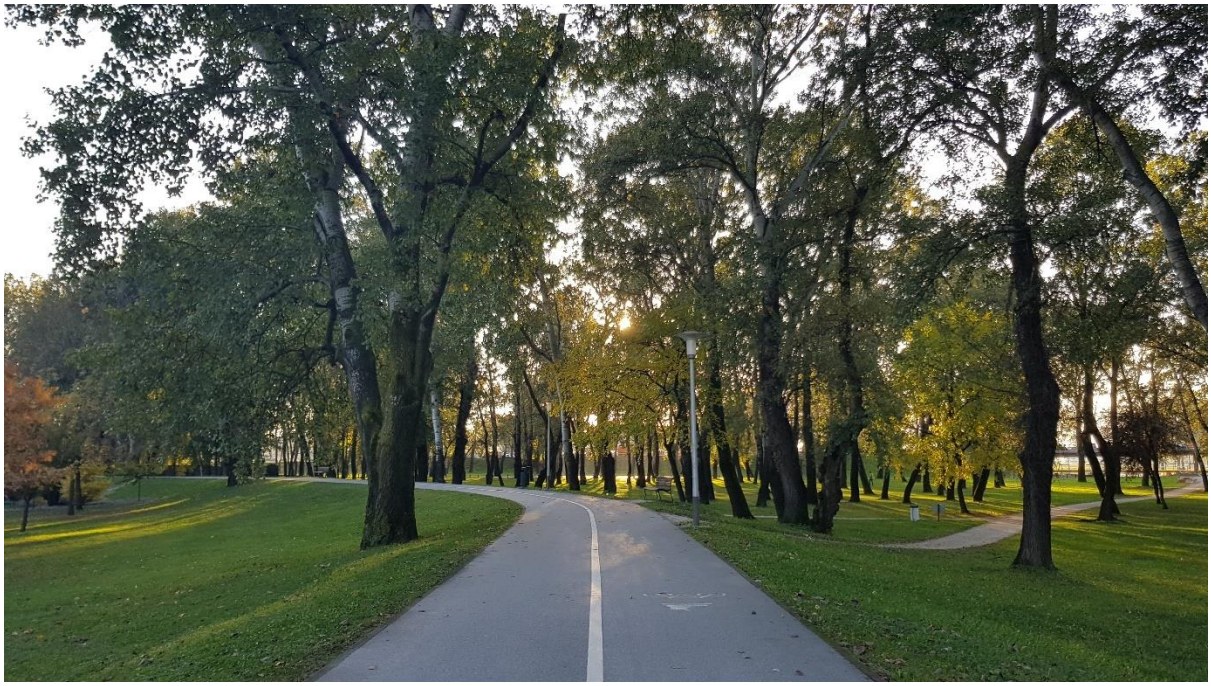


Figure 14 - Biking lane in Bundek Park

Taking the Kids Out marker was chosen by the least number of respondents out of all recreational activities presented to the participants in the Zagreb PPGIS questionnaire. This could be due to the fact that not all respondents have children since the median value on the number of underage children in a household for the sample is 0, meaning that at least half of the respondents do not have underage children in the household. Furthermore, underage children are defined as those being younger than 18 years-old. From the age of 18 years children usually do not need to be accompanied by adults when going out in green spaces. Adolescents aged 12-18, as shown by other research, can independently map the perception and use of places around them in a PPGIS study (Hewitt et al., 2020). Therefore, it can be argued that while mapping this activity the respondents took into account only young children. Because of the specificity of this type of recreational activity and multiple prerequisites that have to be satisfied, lower mapping utilization of this attribute is not unusual. Similar mapping behaviour was also presented in research by Rall et al. (2017) and De Valck et al. (2016). While De Valk et al. concluded that more facilities and infrastructure adjusted for children are needed to enhance mapping behaviour, in the city of Zagreb reasoning for lower utilization of the marker representing Going Out with Kids is probably based on the characteristics of the sample. However, parks were the most mapped UGI type for this recreational activity, further highlighting their importance on a city level.

Dog Walking occurred mostly in parks according to the numbers of placed spatial markers, followed by forests and other UGI. Informality and likely dog-friendliness of the latter could be the reason along with the convenient location for choosing to walk a dog in those spaces, similar to a reasoning found by Pietrzyk-Kaszyńska et al. (2017) for cities in Poland. On the other hand, in Bucharest, parks are used for dog waking mainly because of their proximity and accessibility, as stated by dog walkers (Iojă et al., 2011). Forests on the edges of Berlin were used for dog walking in the research done by Rall et al. (2017). Based on the presented, dog walking is a specific recreational activity where convenience of the place could be of more importance than the facilities. In previous research pet walking emerged as important and largely utilized activity in park forests in the city of Zagreb and those who lived in close proximity to a park forest used it more often for dog walking purposes (Kičić et al., 2020). Furthermore, in Zagreb, even though there are delineated dog parks in the dataset, they are not utilized for the purpose, at least not in this sample where more than 30% of the respondents stated that they own a dog. A reason for that could not be extracted from the PPGIS questionnaire alone; however, it is important to emphasise that more attention should be given to this specific type of visitors to green spaces.

Quantification of various recreational activities in the city of Zagreb further confirmed the results of qualitative analysis, whose results indicated that parks in the city centre that form the green system known as the green horseshoe are less used for recreation (Krajter Ostoić et al., 2020a). Within this city-wide research, similar results have been gathered, that is, only a small amount of marker points for recreational activities were placed in these locations. Possible explanation for this type of behaviour could be alike the one proposed after qualitative analysis of focus group transcripts, in which the locations in the city centre that are loud (see results of CA, Figure 7) and part of touristic attractions could turn down people from recreational use (Krajter Ostoić et al., 2020a). The second possible explanation could be the lower number of participants from the city district Donji Grad. Since the accessibility is one of the most influential factors in green space use, it could be argued that if more people from this city district participated in research, the green horseshoe would emerge as more important for recreational activities. However, city-wide scale allowed all participants to mark any location on the map, including the green horseshoe, hence the results clearly indicate greater importance of the green horseshoe parks and Botanical Garden as providers of Cultural Identity values and perception rather than Recreational opportunities.

5.2.6. Perception of attributes of Aesthetics in the urban green infrastructure of the city of Zagreb

Aesthetic perception of UGI in Zagreb was explored through four different attributes that were presented to the respondents for mapping - Aesthetic Experiences defined as locations that are aesthetically beautiful, Maintained for locations that are perceived to be in a good condition, Naturalness for the locations that can be characterised as natural and Restorative for locations that the respondents perceive as beneficial to their well-being. As previously mentioned in the Material and Methods section, attributes of positive and negative perception were combined within one mapping question. Nevertheless, more respondents chose to map positive perception rather the negative one. Out of four attributes, the ones with higher mapping frequency and also the ones that were chosen by most respondents were Naturalness and Restorative. Maintained and Aesthetic Experiences were also highly mapped by more than 220 respondents each.

In the focus group discussion, naturalness was expressed as the presence of true forest that is well preserved and indicates high biodiversity. Also, naturalness in these discussions was usually expressed in relation to forests, parks, and park forests (Krajter Ostoić et al., 2020a). Quantification of this attribute by using a PPGIS questionnaire further confirmed focus group results. Forests, parks, and park forests were the most often mapped types of UGI in the city of Zagreb associated with naturalness. Furthermore, and in line with the focus group explanation of naturalness, forests were more perceived as natural places than other types of UGI as a result of CA. Naturalness was usually related to those green spaces that seem natural, that is, which do not show signs of built infrastructure or high maintenance expressed by the respondents (Riechers et al., 2016). Peri-urban and urban forests in different studies have been perceived and used because of their natural character. Whether it is by using informal trails that feel more natural (Verlič et al., 2015), experiencing less encounters with people and infrastructure (Aasetre et al., 2016), or perceived quietness (Beckmann-Wübbelt et al., 2021). In the case of Zagreb, Naturalness was also the attribute of Aesthetics, with the largest median distance from home indicating that natural is oftentimes perceived as something further away from home. It can be argued that all of aforementioned reasons reported in scientific literature can be applied for the city of Zagreb as well. However, research has also shown complicated and oftentimes conflicting perceptions different people hold toward forests (Ciesielski and Stereńczak, 2018). Even though forests are perceived as natural areas in the city of Zagreb, people surely have some expectations from these areas and a specific look that they perceive as natural. However,

these results for the city of Zagreb can also indicate that forests are perceived as well-managed and mostly fit into the ideal picture of a natural area. Because of the regular (commercial) forest management employed in forests and forest-covered areas such as Medvednica Nature Park, more contact between foresters and users is needed to reach mutual understanding and to enhance planning and management of forests in Zagreb. Methodological approaches such as workshop participatory mapping and periodically conducting online PPGIS questionnaires could be used to enhance and present to the public the current practice of assessing ecosystem services provided by forests in close relation to urban areas and to decrease the probability of potential conflicts among recreationalists and foresters.

Residents' physical and mental well-being benefits from Restorative effects provided by green spaces. Mental and physical health as well as perceived overall well-being in green spaces are often addressed in different studies in relation to various external factors (Arnberger and Eder, 2015; Korpela et al., 2010; Wood et al., 2018). Restorative effects along with spiritual benefits of urban green spaces were emphasised by the respondents of focus groups as a reasoning for places being their favourite or aesthetically pleasing. With regard to that, previous research has found that even though there are differences in restorative experiences among different green spaces with waterside elements, urban forests and outdoor activity areas providing the highest restorative experience, favourite places in the city regardless of the type may provide equally strong restorative benefits (Korpela et al., 2010). Similarly, Arnberger and Eder (2015) pointed several studies that resulted with no differences in restorative effect among parks and forests and concluded based on their own research in Vienna that people who seek stress relief and those who do not would usually visit similar places. In the city of Zagreb, locations perceived as Restorative emerged as somewhat specific. The CA biplot resulted with placing the perception of restorative locations in a separate quadrant close to the centre of the biplot, but not close to any of the UGI types specifically and not influencing any of the first five dimensions, regardless of being the second most mapped attribute of positive perception. Cartographic representation and NN calculation show grouping of collected spatial markers into few distinctive hotspots in the city of Zagreb. A possible explanation of this result could be in the secondary spatial dataset used since the visual interpretation of hotspots resulted with the conclusion that hotspots are usually located in forest areas or near water features. Before-mentioned Savica Lakes are one of the hotspot locations. Parks containing water features (Maksimir, Bundek, Jarun) in the form of lakes, and the embankment around the Sava River emerged as hotspots. Even though the urban blue areas are not the primary infrastructure

explored in this research, their influence still needs to be emphasised as important. Water features emerged as important for the provision of cultural ecosystem services in other research as well (Baumeister et al., 2020; Plieninger et al., 2013; Rall et al., 2017; Ridding et al., 2018).

When it comes to the perception of other two attributes of positive perception, Maintained and Experiences, people hold toward green spaces in Zagreb, they were grouped together in the CA biplot and placed in the same quadrant. Furthermore, these two attributes are on opposite sides in the biplot in relation to attributes of Naturalness and Restorative, indicating that there is a difference in perception among them. The most pronounced difference is the type of UGI connected with the perception of locations as being maintained and aesthetically pleasing, and that is parks. Parks are usually well designed and well maintained; hence, the perception people hold towards them is in line with their main characteristics. Furthermore, maintenance and different aesthetical experiences were expressed by citizens of Zagreb as attributes of aesthetics as a cultural ecosystem service (Krajter Ostoić et al., 2020a). Hotspot maps indicate that Maksimir Park and parks forming the green system in the city centre emerged as those being perceived as Maintained and as providing Aesthetical Experiences. This result was expected since both places are historically and architecturally important for the city of Zagreb, therefore they are maintained to keep their original appearance. Although other UGI types in Zagreb have also been mapped by the respondents as being well maintained and aesthetically pleasing, parks as a UGI type dominated the perception. However, it should be stated that these two attributes were less used than Naturalness and Restorative, suggesting that sometimes well maintained or heavily designed locations are not of primary importance for the respondents, but that they rather seek different feelings and experiences while spending time in green spaces.

5.2.7. Education and educational possibilities in urban green infrastructure in the city of Zagreb

In comparison with similar mapping questions (Place Attachment and Cultural Identity), Education was mapped by the least number of respondents despite not being the last mapping question where fatigue could significantly affect mapping. The review of practice and research in the fields of urban forestry and green spaces in Croatia in the last three decades detected a shortage of papers dealing with the theme of education in green spaces (Krajter Ostoić et al., 2020b). Furthermore, the existing papers usually do not cover education as a service that could be experienced in green spaces (ibid.). Based on that, a smaller number of spatial markers placed on the map for Education as cultural ecosystem service category can be explained with,

among others, smaller interest for these types of services in practice and research alike. The residents of Zagreb, when asked about the perception of education as a service of green spaces in their city district, usually mentioned the potential of green spaces to be used in educational purposes and often in relation with children's learning (Krajter Ostoić et al., 2020a). Based on the distribution of spatial markers collected with the PPGIS questionnaire the locations perceived as having educational potential or those which are used for education, the importance of Medvednica Mountain, i.e. Medvednica Nature Park, along with other park forests and larger parks in Zagreb has been emphasised. Spatial clustering of the collected spatial markers was observed, further emphasising specific locations in the city of Zagreb perceived as having education potential, whether used or unused. Forests have also previously been detected as bearers of educational cultural ecosystem services (Beckmann-Wübbelt et al., 2021; Plieninger et al., 2013; Rall et al., 2017)

The respondents of the PPGIS questionnaire were not obligated to put markers on the map and were instructed to think of Education as a service aimed at everyone. Less interest shown for educational services of green spaces shows that there is still place for improvement in planning and management of green spaces. A smaller scale research on the specific site of Grmoščica forest showed that education in nature was not often the reason why people visited the forest, and when it was, it was not a priority, but rather an additional activity in the park forest (Kičić et al., 2020). On the other hand, the same research showed predominantly positive attitude towards implementing new educational trails on the whole forest's area. International research shows how education is also not among highly perceived cultural ecosystem services (Baumeister et al., 2020; Beichler, 2015; Bieling et al., 2014).

However, it should be emphasised that locations mapped as having Educational potential were further from the respondents' homes. Although the discussion on calculated distances will be given later in this work, it could be argued that when it comes to education it does not have to be only formal and appear in specially predicted places, but rather everywhere where people can learn from each other about nature (Krajter Ostoić et al., 2020a; Riechers et al., 2016). Especially in times where alienation from nature negatively affects human-nature interactions (Riechers et al., 2016).

5.2.8. Urban green infrastructure as holder of Zagreb's Cultural Identity

Cultural Identity was the last explored cultural ecosystem service in the PPGIS questionnaire employed in the city of Zagreb. This category elicited weaker discussion among focus group participants in the previous research, which could be due to confined AOI, since in the PPGIS questionnaire Cultural Identity was mapped by 350 respondents placing 851 spatial markers on a digital map. Spatial distribution indicates that predominantly UGI located in the city centre are perceived as being symbolically important for the city of Zagreb (an example is presented in Figure 15). The majority of those locations are in the UGI category of parks and park forests, despite the fact that city-wide different parks are perceived as dominant.

Figure 15 - Park in Zagreb's city centre

In Germany, similar mapping behaviour has been observed where for the city of Berlin and Rostock most of the cultural identity values are found in the city centre (Beichler, 2015; Rall et al., 2017). Similarly, on the country level in Switzerland, the majority of heritage values are found near the urban settlements (Jaligot et al., 2019). Spatial pattern of the collected markers is also very clustered. The highest clustering that occurs for this specific cultural ecosystem service reveals almost uniformity in perception among the respondents engaged with this research. Sometimes attributed as cultural heritage values, this perception in different spatial

and cultural contexts usually also emerges with the most clustered spatial distribution (see Fagerholm et al., 2019; Rall et al., 2017).

Cultural Identity is usually associated with locations that are visited by many people, which are well-known even beyond the city limits or are special in some way (Krajter Ostoić et al., 2020a). Therefore, this result just highlights those places in the city of Zagreb that should be important from the touristic perspective as well, while special attention should be put on those places regarding planning and management. Oftentimes, as in the case of the citizens of Berlin, but possibly similarly in the case for Zagreb, historical sites and their preservation are motives for mapping specific locations (Riechers et al., 2016).

5.2.9. Perception of Disservices provided by urban green infrastructure in the city of Zagreb

In relation to attributes representing Aesthetics, spatial markers representing attributes of Disservices (or negative perception) were mapped less often by the respondents and resulted with a smaller number of spatial markers used further for analyses. It should be emphasised here that even though attributes of opposite perceptions were aggregated into one mapping question, the respondents perceived disservices of UGI in the city of Zagreb strongly enough to place a spatial marker on the map, proving the statement that respondents will use markers with those attributes that are important for their perception (Brown and Kyttä, 2014). This is not an unexpected mapping behaviour since research literature where PPGIS is employed for mapping cultural ecosystem services and disservices together has reported lower frequencies of spatial data collected for disservices (Ives et al., 2017; Plieninger et al., 2013; Rall et al., 2017). Furthermore, the perception people tend to hold toward green spaces is usually more positive than negative (Ives et al., 2017). This could partly explain the lower frequency of mapping spatial attributes representing disservices in this study. Nevertheless, more than half of the respondents engaged with this research mapped at least one of the attributes of Disservices.

Perception of places being Unmaintained and Noisy predominate negative perception based on the number of spatial markers collected. The PPGIS questionnaire's design employed for this research was to be concise in defining attributes offered for mapping. However, diverse respondents may comprehend differently some attributes such as Unmaintained. Since the clear definition of Unmaintained was not given upfront to the respondents, it is reasonable to

conclude that the motivations for mapping this attribute are diverse. Still, out of all disservice attributes, the largest amount of people chose to map locations perceived as unmaintained, hence the highest amount of collected spatial markers. Distribution of spatial markers for Unmaintained across UGI types in Zagreb is rather balanced, but higher frequency of mapped points has been observed for other as a UGI type. Since the definition of a UGI type was adopted from the LU dataset clearly emphasises lesser amount of maintenance dedicated to those places, this result is not unexpected. Research shows that the perception of insufficient management along with litter-related problems is present among visitors of brownfields in Leipzig (Palliwoda and Priess, 2021). Unmaintained vegetation can be a factor that triggers a sense of fear in green spaces according to a review on the topic by Sreetheran and Konijnendijk van den Bosch (2014). Indeed, the results of CA attest that these two perceptions (Unmaintained and Scary) are interconnected in the city of Zagreb and this connection is manifested in other UGI type. These results at first indicate that there is a strong relationship among other UGI type and the perception of disservices, yet those places are highly used for dog walking and biking, indicating that this relationship is not as straightforward. This is in line with statement that there are trade-offs present among services and disservices (Roman et al., 2021). As expressed in the case of Zagreb, accepting some disservices may balance other good things about the perceived or used UGI. Similar conclusions have also been reported in scientific literature, where the lack of formality provided by such places is sometimes perceived as an asset for users seeking specific activity or experience (Palliwoda and Priess, 2021; Pietrzyk-Kaszyńska et al., 2017). Since Scary as an attribute of disservice is not one of the frequently used spatial markers (45 included in analysis), the significance of this result is not as strong, but should be considered important for planning and management.

Since some parks in the city of Zagreb are also perceived as unmaintained, it can be argued that the issue of insufficient management of the vegetation is not predominant in parks, but rather litter and possibly worn-out park equipment. Lack of waste bins and presence of litter have been previously indicated as highly ranked perceived problems for citizens of Zagreb (Krajter Ostoić et al., 2017). Regarding the presence of litter, illegal waste disposal was as well strongly perceived and expressed by visitors of Grmoščica park forest in Zagreb (Kičić et al., 2020). Since park forests are used and managed similarly across Zagreb, it could be concluded that the illegal waste disposal may be a significant contributor to the perception of unmaintained locations. Yet other possible sources of disservices cannot be completely excluded. The collected spatial markers for perception of Unmaintained locations show

dispersion along the city, while at the same time this is an attribute with the lowest median value of placed spatial markers in relation to home location. Therefore, more research is needed to completely understand this specific attribute of disservice and its manifestation in urban green spaces in general, which could emerge with significant contribution to improving UGI management in cities.

Spatial distribution of the collected markers representing Noisy locations indicates that highly visited parks which are often mentioned as providers of different cultural ecosystem services are at the same time perceived as noisy, probably due to a high number of visitors producing noise. Here it is important to highlight Zrinjevac Park, located in the city centre, which emerged as the noisy hotspot. Alongside high attendance from residents and tourists alike due to its historic importance and location in the city centre, this park is relatively small and encircled with traffic roads and railways. It can be argued that the perception of noise at this place is not a by-product of functioning of this specific park, but rather results from its surroundings. Similar can be stated for other locations perceived as noisy, especially for tree alleys since the CA resulted with a link between the perception of Noise and this specific UGI type in Zagreb. Even though it is not produced by the ecosystem and not a disservice per se, it is one of the most important negative perceptions people hold toward spending time in UGI, especially when it comes to anthropogenic noise (Baumeister et al., 2022). Furthermore, research on sounds visitors perceive in parks in Rostock (Germany) has shown that street noise dominates other sounds in occurrence of perception and loudness (Liu et al., 2019).

The least mapped attribute in general is Conflicts with other users. Based on the results conflicts are more likely to happen in parks where there is a high number of visitors, especially in more famous and visited parks in Zagreb. However, it is interesting that none of the respondents mapped conflicts with other users in any of the park forests in Zagreb. However, based on previous research conducted in Grmoščica park forest, conflicts in such areas could emerge between different types of users and their potentially conflicting activities (Kičić et al., 2020). Small number of spatial markers collected for Conflicts with other users do not allow generalization or complete exclusion of possible conflicts among users in those locations, especially because all presented spatial markers of recreational activities were mapped in park forests.

A PPGIS study conducted on the perception of cultural ecosystem services and negative characteristics of green spaces in Berlin resulted with negative characteristics being perceived

mostly in the city centre. Similar cannot be stated for the city of Zagreb based on the distribution of collected spatial markers. Even though the distribution of markers shows a trend toward clustering, Z-scores are low and the produced hotspot maps visually confirm more dispersed patterns of spatial markers. This is especially true for locations perceived as scary and those where conflicts could emerge. Low clustering values of mentioned attributes of disservices could be in part due to a small number of spatial markers collected and employed for analysis.

Ona the city-level, CA resulted with distinguishing and bundling negative perception within the second dimension. The perception of disservices together with everyday recreational activities was opposed to locations bringing cultural identity, educational potential, and aesthetic experience, that is, the more intangible perceptions of locations. Similar pattern with the perception of disservices and recreational use contrasting the immaterial perception of place has been reported by Plieninger et al. (2013). Also, other studies report findings of bundles of cultural ecosystem services (Ko and Son, 2018; Rall et al., 2017). Clear distinction between the perception of services and disservices with regard to the type of UGI has not been found, but it can be stated based on the result of CA that sometimes people are willing to use negatively perceived locations if they are purposeful.

Despite the fact that attributes of Disservices were less mapped by the respondents engaged with the PPGIS questionnaire in Zagreb, the collected data and results of the conducted analyses produced useful information. Offered attributes of Disservices do not emerge exclusively from functioning of ecosystems, but rather they originate from other sources such as noise from nearby traffic or lack of proper maintenance, which could hinder interpretation of attributes as ecosystem disservices, rather defining them as negative perception. However, research has shown that the existing ecosystem disservice typologies are still not sufficient enough to capture the perception of disservices completely because the anthropogenically induced disservices are always present in the perception (Baumeister et al., 2022; Plieninger et al., 2013). Also, decision on the attributes offered in the PPGIS questionnaire is based on focus group interviews conducted in Zagreb, so those attributes that were emphasised by the participants are used and understood as important for the local context. Furthermore, the proposed attributes are concordant with those employed previously in similar research such as by Ives et al. (2017) and Rall et al. (2017). Regardless of the attributes, negative perception and its spatial distribution emerged as a result of the conducted PPGIS study in Zagreb. To improve planning and management practices in Zagreb, these results can provide a solid

background. In addition, research focused solely on disservices with or without the spatial component would further enhance these findings. Finally, as presented, sometimes benefits provided by the UGI and disservices perceived there are not mutually exclusive, but rather they interrelate in an urban landscape, further highlighting the need to include the information on disservices in the current planning and management practice (Haase et al., 2014).

Based on the presented results, the first hypothesis that cultural ecosystem services and disservices are not randomly distributed across the urban landscape can be confirmed. Indeed, there is enough evidence that UGI type is connected with and influences the perception of cultural ecosystem services and disservices in the city of Zagreb.

5.2.10. Perception of cultural ecosystem services and disservices in relation to distance from respondents' home

Accessibility of forests or other urban green spaces is almost always a strong predictor of their use (Hegetschweiler et al., 2017; Ridding et al., 2018). Distance from the respondents' home location to locations of specific perception or use can be a valuable input for spatial planning and management of green spaces (Beichler, 2015). As previously stated, within this research Euclidean distance was used to measure the distance between approximate home address of the respondent and each spatial marker placed by that same respondent on a digital map of Zagreb. Calculation of linear or metric distance does not take into consideration the complexity of the street network between the two points in space, which results with underestimating the real distance the respondent need to cross in city (Chiang and Li, 2019). Nevertheless, Euclidean distance is a good approximation of the distance where a specific attribute is perceived, and it is often employed in scientific research for this purpose (Beichler, 2015; De Valck et al., 2016; Fagerholm et al., 2016; Jaligot et al., 2019; Lehto et al., 2022; Ridding et al., 2018). Likewise, WHO proposes a linear distance of 300 m from the nearest urban green space for the resident as a rule of thumb in spatial planning. Hence, there are scientific and policy-based grounds for using linear distance. Furthermore, due to methodological approach employed here, the exact distance is not of uttermost importance for the interpretation of gathered results, but rather the approximation alone is sufficient for the purpose. If the sample of respondents is large enough, there are higher chances that collective truth is attained, making the observed patterns in measured distances more reliable (Brown and Fagerholm, 2015). Since 5,671 distances have

been measured in this research, it is believed that the sample is large enough to enable meaningful interpretation. For specific attributes, a rather small number of spatial markers was collected with PPGIS and consequently a small amount of distance measurements was done. Those spatial markers represent disservices: Conflicts (22) and Scary (44). However, distances measured for mentioned attributes of disservices do not deviate from the results of distances measured for other attributes and, even though with caution, they are used and interpreted as valid. By using a centroid of the polygon as an approximate home location, measurement error that could emerge was accepted; however, it is also believed that such error would not hinder the results.

The median distance was employed as the measure for comparison because maximum distances measured for some attributes were above 20 km from the respondents' home, skewing the distribution to further distances, and thus influencing mean values. Indeed, median values calculated are somewhat lower and more reliable as a measure of distance. The highest median value was calculated for Hiking as a recreational activity. Based on a produced heat map for Hiking, the respondents usually engage in hiking as a recreational activity on the slopes of Medvednica Mountain, marking peaks and mountain huts throughout the area. Naturally, these places are located further away from the respondents' homes and distances for Hiking differentiate from all other distances by the attribute measured. Similar results were also obtained in Belgium where largest distances were obtained for hiking (De Valck et al., 2016). The second furthest distance among recreational activities was calculated for passive recreation attribute of Watching Nature, while the largest distance among aesthetic attributes was measured for Naturalness. These results further complement the CA biplot produced based on PPGIS data where Hiking, Watching Nature, and Naturalness were grouped together provided by primary forests. Therefore, distance analysis further acknowledged relationship between the three attributes and forests as UGI type. It can be stated that hiking is not an everyday activity for the majority of citizens of Zagreb, alike other citizens in Europe. Also, when certain landscape features are needed for a recreational activity to be fulfilled, measured distances are larger since some people are willing to travel further to these landscapes (Lehto et al., 2022). Distances measured for Hiking verify the usability of the method employed.

Regarding other activities placed under the cultural ecosystem service category of recreation, their median distances are shorter, indicating that there are types of UGI closer to the respondent's home capable of providing recreational opportunities. This is not unusual since similar research has also reported that locations used for recreational purposes are closer to the

respondent's home (Fagerholm et al., 2019, 2016). The shortest median distances were calculated for recreational activities of Dog Walking and Running, which is also similar to the results obtained in Belgium and Sweden (De Valck et al., 2016; Lehto et al., 2022). Their explanation of gathered distances can be applied for the city of Zagreb as well, where those activities can be described as routine-based, i.e. as activities that are done repetitively and, conveniently, locations closer to home are used (De Valck et al., 2016). For the city of Zagreb, one additional recreational activity can be added to the list, which is Taking the Kids Out. Even though markers for this activity are located further from home, the difference in median distances is around 500 m which is, based on the scale of the research. not far, and the statistical difference between the distances for those three recreational activities was not found (see Appendix 3). These results indicate the importance of the near home UGI types that are used for such recreational activities and should be maintained to keep providing them in the future.

Interesting pattern emerged from distance analysis employed for aesthetics and disservice attributes. For all four attributers of disservices, median values were lower than for median values where the aesthetic appreciation of UGI in Zagreb is perceived. Scientific literature reported similar findings where aesthetic values are perceived further from the respondents' homes and are related to natural environments that are not immediately accessible (Fagerholm et al., 2016). Also, in a large study employed in Helsinki, neighbourhoods places perceived as having high quality were located further than places perceived as negative, and the difference between those distances was significant (Kyttä et al., 2013). Furthermore, the lowest median value among all attributes of cultural ecosystem services and disservices explored was calculated for UGI locations perceived as Unmaintained. This result should be stressed out because it can be used as an input for enhancing management of UGI in the city of Zagreb. Disservices, even though perceived to a lesser extent in relation to positive attributes of aesthetics, are perceived as being closer to the respondents' homes. In combination with specific UGI types that were highlighted as holders of different disservices, an overview of the topic was delivered, opening new research questions and serving as an important input for improving UGI planning and management in the city of Zagreb.

Measured distances for cultural ecosystem services of Education and Cultural Identity have among highest median values calculated. Interestingly, those services in research on a similar spatial scale emerged with lower values for distance to the respondent's home (Beichler, 2015). Also, distances for Education statistically differed, with the majority of distances calculated for other cultural ecosystem service and disservice attributes in largely being perceived as further

away. Based on the results of the focus group interview conducted in Zagreb prior to PPGIS research, some reasoning behind this result could be extracted. For example, that the respondents are generally less aware of the possibility of education in urban nature and that the locations used for education need to have special characteristics, such as historical parks or places with appropriate infrastructure (Krajter Ostoić et al., 2020a). Those characteristics can be found in larger UGI locations usually placed further away from residential areas. If distance for educational potential of UGI in Zagreb wants to be reduced, more effort should be placed in enriching everyday places such as greenery around residential buildings or smaller parks with equipment that can be used for educational purposes. Along with Education, distances for locations perceived as holders of Cultural Identity resulted in higher median values in relation to the majority of other explored attributes of perception. Conversely to Education, locations of Cultural Identity represent not only heritage values, but also touristic potential, hence the most well-known locations of UGI are marked as holders of this service, further accented with having the highest spatial autocorrelation. Since those locations are usually found in the city centre or close to the city centre, larger distances are expected (Rall et al., 2017). Additionally, scientific literature also reports higher values for culture and heritage further away from the respondents' homes throughout the European landscapes (Fagerholm et al., 2019).

To conclude, distance between the respondent's home location and placed spatial markers representing distinctive attributes of perception toward cultural ecosystem service and disservice can be used to explain attributes' spatial distribution and variation in the city of Zagreb. Calculated measurements present valuable data which when combined with other metrics and spatial entities complete the information about the perception of cultural ecosystem services and disservices provided by UGI in the city of Zagreb.

5.2.11. Specificity of the urban-rural gradient in the city of Zagreb

Within the PPGIS research employed on a landscape/country level, the urban-rural gradient has been oftentimes expressed through placing specific spatial markers close or further away from urban areas. Examples of this kind of analyses are frequent in PPGIS literature (Beverly et al., 2008; Fagerholm et al., 2016; Jaligot et al., 2019). On a smaller spatial scale such as one city, the urban-rural gradient is revealed through different perception of cultural ecosystem services in relation to urban green space type providing it and the part of the city where those spaces are located (Rall et al., 2017; Riechers et al., 2019). The urban-rural gradient is in most

cases expressed through culturally important locations and those providing social opportunities located near the city centre, while nature-oriented and recreational services are perceived further from the city-centre and near the peri-urban part of the city (ibid.). In this research, the urban-rural gradient was explored by comparing frequencies of spatial markers' attributes being placed in each city district. It is acknowledged that a more precise result could be obtained using defined UGI types and city districts, but due to spatial heterogeneity and specificity of some UGI types such as the Botanical/Zoo garden and subsequent high NA values, the analysis on this level was not possible. However, this differentiation on the city-level is satisfying and enables a meaningful analysis. The existing research presented with the results that residents often visit green spaces in their administrative unit if there is enough of them, while those who live near less green space often visit green spaces in other administrative units (Luz et al., 2019). Therefore, the administrative unit of a city district for the city of Zagreb should provide enough variation for meaningful and contextualised interpretation.

The results of analyses employed for testing urban-rural gradient were interesting and indeed different with regard to city districts in the city of Zagreb. Foremost, the importance of the Maksimir Park and the subsequent city district, Maksimir, was once more highlighted in cluster analysis as a category on its own. Maksimir Park has already been mentioned several times during this work as being perceived as an important provider of different services in the city of Zagreb. Maksimir with its history is important for citizens and tourists alike, and it is one of the most popular and the most well-known green spaces in the city. Due to its popularity and versatile landscape with water and forest elements mixing with highly maintained (landscaped) places and appropriate visitor infrastructure in the park, even if the respondents did not know any other location, it could be argued that they placed their spatial marker in Maksimir Park. This is also an important result and city-wide important hotspot of cultural ecosystem services, but also of disservices' perception, meaning that even though park administration is adequately managing the park, there is still room for improvement. The second cluster that emerged is arguably even more important than the first one highlighting Maksimir city district.

In the second cluster there are city districts in the city of Zagreb for which the smallest number of spatial markers was collected. This is an important finding especially with regard to research results presented by Luz et al. (2019). With the exception of Brezovica city district on the south of Zagreb, other city districts in the cluster (Stenjevec, Trešnjevka - sjever, Donja Dubrava, Gornja Dubrava) are categorized with small number of available UGI that can be perceived and used. Since the whole city of Zagreb was AOI and the respondents were not restricted with

any boundaries for mapping, smaller number of respondents from a specific city district would be balanced with quality green spaces that other people perceive, use, and map in that city district. However, this was not the case in these city districts. Lack of UGI in those city districts is evident and also puts pressure on a surrounding UGI in other city districts for those people who seek contact with nature. The MEA itself stress the importance of cultural ecosystem services for human well-being and the research provided proof for this statement (Beckmann-Wübbelt et al., 2021; Bieling et al., 2014; Fagerholm et al., 2016). This result should be important for local planners and managers of green spaces and encourage important dialogue between them and residents to find a way to improve the current state. Furthermore, this should be a priority because cultural ecosystem services are irreplaceable once lost and if this state becomes a *status quo* in these city districts, many problems could occur in the future. Brezovica, on the other hand, is rich in forests, but it is also a rural-like part of the city with very little highly maintained UGI such as parks. Here, the configuration of the landscape along with somewhat different lifestyle could be the reason behind small number of collected spatial markers and low number of respondents engaging with the PPGIS questionnaire respectively.

The next two clusters each consist of one city district, the first being Podsljeme and the second Trešnjevka - jug. Both of these city districts are characterised with already mentioned important UGI locations in Zagreb. Podsljeme is heavily influenced by Medvednica Nature Park whose forests cover significant city district's area. Furthermore, some of the most popular hiking trails are located within the city district boundaries as well as the mountain's peak – Sljeme. Medvednica Nature Park is also stressed throughout this work as a significant part of UGI in Zagreb. Since the management of Nature Park is independent from the City of Zagreb, these results are not only important for city administration, but also for Nature Park's management. Forests on the Medvednica slopes located in Podsljeme city district are often used for hiking and watching nature, perceived as natural and probably as an area important for biodiversity located further away from everyday used UGI present with similar urban-rural expression as in previously mentioned research in Europe. Trešnjevka – jug is also heavily influenced with one specific UGI location, Jarun Park. Also, it can be argued that this park balances the lack of appropriate UGI locations in neighbouring city districts with being large and diverse enough to accommodate a large number of visitors and uses. Contrary to Maksimir, Jarun is characterised with a large artificial lake, sport tracks and fields and a number of coffee shops. As such Jarun is suitable for diversity of activities like walking, biking but also for socializing.

Jarun is also recognized as noisy, a location of conflicts and somewhat unmaintained. Its importance beyond the city district Trešnjevka - jug is acknowledged on the city-level.

Another argument for the existence of urban-rural gradient in the city of Zagreb is also the last cluster in the dendrogram that consists of three city districts: Donji Grad, Gornji Grad - Medveščak and Novi Zagreb - istok (Figure 11). These city districts located in the middle of the city of Zagreb are characterised with locations holding Cultural Identity values of the city of Zagreb and are also hotspots for Socializing. Naturally, all historically important locations are usually found near the old city centre and in the case of the city of Zagreb, these are square parks and the Botanical Garden within the green horseshoe system, but also park forests located in the city centre and used by citizens and tourists alike. The third park – Bundek – is located in the city district Novi Zagreb – istok and is the third largest park in Zagreb, again characterised by water features, a lot of visitor infrastructure and significant amount of vegetation. Since the Sava River divides the city of Zagreb into old (north) and new (south) part, Bundek can be understood as the hotspot location for citizens below the Sava River in the new part of the city. The last and the largest cluster consists of all other city districts which present those city districts that are green enough to provide to its residents and other citizens UGI types and locations that cover their basic needs.

Based on the conducted analysis and visual interpretation of produced map, it can be concluded that the urban-rural gradient is present in the city of Zagreb, but not in the regular city centre to city perimeter linearity. Urban-rural gradient is expressed through city centre being important for cultural identity, Medvednica Nature Park being a natural area on the north, and Brezovica on the south of the city centre as a rural area without recognition from the citizens regarding cultural ecosystem services. Highlighted city districts with low provision of UGI are located on the west and east from city centre; however, based on their spatial configuration they are predominantly urban. To conclude, urban-rural gradient in the city of Zagreb exists but it is dependent on the available UGI, not only in the respective city district, but also the neighbouring ones.

5.2.12. Socio-demographic and visiting behaviour characteristics of respondents in the sample

Target number of respondents proposed for this research was 384 because this number of respondents allows the generalization of gathered results and is also in line with previously employed research in the city of Zagreb (Krajter Ostoić et al., 2017). Because this is the first study in the city of Zagreb, and even wider, which employed a PPGIS questionnaire as data collection method, non-probability sampling was employed. The weakness of the applied approach has been acknowledged; however, since this research is exploratory it is believed that this approach is suitable and concordant with sampling used in similar studies (Fagerholm et al., 2021b; Rall et al., 2017). Furthermore, PPGIS studies often report low response rates (Brown et al., 2014; Brown and Fagerholm, 2015; De Valck et al., 2016; Garcia et al., 2020; Jaligot et al., 2019). Achieving higher participation rates in the PPGIS research using probability sampling is usually quite difficult (Brown and Fagerholm, 2015). Since the PPGIS is predominantly a spatially-oriented method, spatial distribution of the respondents' homes is also important in data analysis and interpretation.

More than the initially aimed number of respondents participated in the PPGIS research. However, during the data cleaning process some of the respondents had to be removed from the database, resulting in 384 respondents who participated in the research either completing the socio-demographic part, the visiting behaviour part, the mapping part or all of mentioned. Because of the differing number of respondents in different sections of the questionnaire, one should be careful when interpreting the results and trying to generalize the collected sample. Significant amount of spatial data collected within this research enables more generalizable conclusions. However, this is not the case for socio-demographic part, and the interpretation will be given in relation to the sample of population included into this research.

Due to the sampling method employed, the gathered sample of population when it comes to socio-demographic characteristics deviates from the general population in the city of Zagreb. This trade-off that usually occurs between meaningful amount of spatial data gathered with PPGIS questionnaire and representative sample of respondents is well documented in scientific literature (Brown and Fagerholm, 2015). It is often the case that the sample of respondents gathered with probabilistic sampling, despite the targeting effort, deviates from the general population (Fagerholm et al., 2021b; Pietrzyk-Kaszyńska et al., 2017; Rall et al., 2017). Sample of the population collected for Zagreb is characterised with overrepresentation of women, middle-aged and highly educated respondents. The sample characterised with

overrepresentation of highly educated and middle-aged respondents is often reported in scientific literature dealing with PPGIS practice (Baumeister et al., 2020; Beckmann-Wübbelt et al., 2021; Fagerholm et al., 2021b; Pietrzyk-Kaszyńska et al., 2017; Rall et al., 2017). It can be argued that highly educated and middle-aged people feel more at ease with thinking about and producing spatial data in a computer/smartphone environment. The share of female respondents in the sample of Zagreb is slightly larger than in general population; however, there is no clear indication that this is the rule in PPGIS studies. Some studies report overrepresentation of women (Fagerholm et al., 2021b), some overrepresentation of men (Baumeister et al., 2020), and some a rather balanced sample of respondents gender-wise in relation to local context (Brown et al., 2014). Since the information about the age of the respondents has been collected with an open-ended question where the respondents could write in the number indicating their age, it was possible to calculate the mean age of the respondents within the sample. For the simplicity of analyses and inference, the data about the age was aggregated into age groups. Calculated mean age of the sample still indicates a rather young sample (37.7 years), but it is relatively close to the mean age of citizens of Zagreb (41.6 years). It is evident that there is an underrepresentation of older people in the sample (60+ years), despite the targeted effort to include this part of the society in the research. Older residents of the cities are important users of green spaces and usually benefit more from this interaction, resulting in better well-being (Ode Sang et al., 2016). Engaging older residents into this kind of research is often a complicated task without a facilitator who would help since older people find computer map interface difficult and demanding (Rzeszewski and Kotus, 2019). Research and PPGIS design acknowledged the possible issue of older people and throughout the process of designing and conducting research special attention was put on making mapping exercise easy and understandable for all.

The second contextual question page asked residents to state their usual visiting behaviour in regard to green spaces in the city of Zagreb. It was believed that visiting habits and behaviours would influence the perception and use of UGI in the city of Zagreb based on previous research findings (Bertram et al., 2017). First contextual questions asked were about the length of residence in one's city district and the city of Zagreb respectively. Length of residence in one place can be used as a proxy for familiarity with and knowledge about the AOI, where longer residency indicates better self-estimated knowledge (Fagerholm et al., 2016). On average, the respondents have been living in their city district for almost 19 years and in the city of Zagreb for approximately 30 years. It can be concluded that the average respondent knows its

surroundings well enough to produce quality spatial data. Based on the amount of collected spatial data and afterwards the amount of data that was used further in the analysis it can be concluded that the length of residence had a positive impact on the result of mapping exercise.

Expressed visiting frequency in the sample revealed that the sample is rather biased in terms of visiting frequency to green spaces, in which cumulatively 83% of the respondents visit green spaces at least once a week. Also, similar results have been reported in a PPGIS study for the city of Berlin, in which more than 75% of the respondents stated visiting green spaces once a week or frequently (Rall et al., 2017). Nevertheless, it was expected that those who visit green spaces more frequently would be more inclined into engaging with research on green spaces. Furthermore, when asked about the part of the week when they usually visit green spaces, around half of the respondents stated visiting green spaces throughout the whole week in relation to specifically weekdays or weekends. Because the sample is inclined toward frequent visitors to green spaces, this visiting behaviour is expected, and is also in line with reports from scientific literature (Bertram et al., 2017). Frequent visitors to green spaces who are also employed dominate the sample, hence visiting green spaces in Zagreb in the afternoon as the majority of the respondents stated is a rather common behaviour. The duration of visits, however, varied and range from stated 30 minutes to more than two hours, while the least number of respondents stated spending time in green spaces in Zagreb for less than 30 minutes. The respondents stated to a higher extent that they spend between one and two hours in green spaces. The same pattern also emerged in the sample of visitors to park forest Grmoščica in the city of Zagreb (Kičić et al., 2020), and also in other similar studies found in scientific literature (Zwierzchowska et al., 2018). In this research, the respondents also dominantly expressed that they visited green spaces in the city of Zagreb in company either spouse, friend, or kids, while only 23% of the respondents stated that they usually visit green spaces alone.

Accessibility has already been mentioned as an important predictor for green space use (Hegetschweiler et al., 2017), especially since the majority of people in the sample stated visiting green spaces on foot. With regard to distances measured (see Distances) that resulted with somewhat lower median values for everyday activities, it can be concluded that people in the Zagreb usually have an accessible and appropriate UGI near to their residence which they can visit frequently.

5.2.13. Influence of socio-demographic characteristics on expressed perception of cultural ecosystem services and disservices in the city of Zagreb

Contextual questions are used to give more background data on the respondents to make interpretation of the gathered results more insightful. Fairly good amount of data has been collected in the city of Zagreb and the number of respondents was comparable to that collected in similar studies in Europe (Beckmann-Wübbelt et al., 2021; Korpilo et al., 2021; Rall et al., 2017; Ridding et al., 2018). Influence of the socio-demographic and visiting behaviour on the perception expressed through mapping frequency of specific attributes of cultural ecosystem services and disservices is explored employing correlations and GLM.

Correlations overall resulted with positive and statistically significant correlation coefficients between mapping frequency of attributes for both socio-demographic and visiting behaviour variables. Based on that, it can be concluded that overall a rather small difference between the respondents with different characteristics and their mapping frequency was found. It should be stated that this could be due to a mapping exercise design with separate questions for different services, where probably some of the respondents felt that placing spatial markers on the map was compulsory, when it was not, hence resulting with similar mapping frequencies for some cultural ecosystem services (Place Attachment, Education and Cultural Identity). Nevertheless, not all correlation coefficients indicated high and statistically significant relationship between the variables. For example, the results for respondents who finished elementary school in relation to respondents with other levels of education; or the respondents who characterised their visiting behaviour as seldom in relation to others who expressed more frequently visitor behaviour. This is probably not due to the explicit difference in perception, but rather a small number of respondents who expressed these characteristics, therefore the conclusion on the difference would be ill-conceived. Independently of these respondents smaller, but statistically significant correlation coefficients were calculated for some other variables, indicating possible differences in the perception among the respondents with different characteristics. Probably the most expressed example is for calculated correlation coefficients between respondents with different employment statuses and different visiting patterns. These results indicate possible differences in perception expressed by students and retired people with regard to rest of the sample. As for the visiting patterns, out of all explored variables this one resulted with the lowest correlation coefficients between the variables. Interestingly, those who stated visiting green spaces once a week had the highest mapping relationship with others. However, to bring conclusion on how all of these variables influence mapping behaviour, and subsequently

perception, GMLs were produced by modelling the number of placed spatial markers on the map in relation to socio-demographic characteristics of the respondents and their stated visiting behaviour. Using GLM in modelling, the respondents' response to the questionnaire has already been employed in the PPGIS research and it proved their usefulness (Dade et al., 2020; Fagerholm et al., 2019; Rall et al., 2017). The produced models highlighted some differences in mapping behaviour worth mentioning here and discussing in detail.

Correlation coefficients for mapping behaviour between gender variables were rather high and statistically significant, and similarity in mapping behaviour is evident from the produced models. However, males mapped significantly more markers for Biking than females. Sometimes in literature gender differences in perception and use of green space have been discovered (Ode Sang et al., 2016; Plieninger et al., 2013; Schipperijn et al., 2010), while sometimes those differences have not been found (Baumeister et al., 2022; Chiesura, 2004; Fischer et al., 2018; Sreetheran and Konijnendijk van den Bosch, 2014). For the respondents in this research the only difference found was for the biking as a recreational activity. Therefore, it can be concluded that there is almost no difference in mapping behaviour and perception between genders within this sample. Furthermore, in a Europe-wide research on park use, gender was not found as an influencing variable leading to conclusion, as stated by authors, that other variables are more important when searching for differences in park use (Fischer et al., 2018).

Age categories mostly did not influence mapping behaviour; however, some specificities were noticed, for example, the respondents in the age group 31-45 placed significantly more spatial markers indicating Taking the Kids Out than others. Since people of that age usually have little children, this could explain the choice of this attribute of recreation. Furthermore, respondents of the same age category placed significantly less markers for Hiking, Watching Nature and Aesthetic Experiences compared to others, thus again it could be argued that having children influenced the choice of spatial markers and the perception respondents hold toward UGI in Zagreb. Middle-aged people in other research valued available infrastructure (Palliwoda and Priess, 2021), hence similar can be concluded for the city of Zagreb. Respondents in the age category of 31-45 also put more markers attributing locations as Unmaintained, while those in the age category 46-60 put more spatial markers attributing Maintained locations. Research has shown that older people put more emphasis on the aesthetic benefits of green spaces (Ode Sang et al., 2016; Palliwoda and Priess, 2021). Therefore, partially comparable results were gathered in our study. It should be emphasised that other attributes of positive perception did not emerge

with the same results. Even though mapping behaviour differs between some age categories, high correlation coefficients and GLM results do not show a straightforward difference between age categories, hence it cannot be stated that age influences perception to a large extent, but rather that mapping behaviour also depends on other variables that were not explored.

People with Master's and PhD degrees expressed higher perception of Place Attachment, Cultural identity, Education (only PhD), Aesthetic Experiences of UGI in Zagreb and put significantly more markers for Walking. Education proved important for higher appreciation of immaterial cultural ecosystem services. Education proved to be an influencing factor in other studies on the park and other green space's perception and use throughout Europe (Fischer et al., 2018; Krajter Ostoić et al., 2017; Rall et al., 2017; Riechers et al., 2018).

The final socio-demographic variable that was tested in detail was the respondents' employment status in relation to their mapping behaviour. The variable that emerged as important and differentiating was that of the student, since students mapped more Maintained locations, Educational and Cultural Identity services. Unemployed respondents mapped more Biking and more Cultural Identity services. Retired and self-employed respondents in the sample mapped more potential or emerging Conflicts with other people in the UGI in Zagreb. Person's occupation and current work emerged as important variables when exploring different park uses throughout the Europe with an influence on physical, social and nature-related use (Fischer et al., 2018).

Based on the presented results, there are some indications that socio-demographic characteristics of the respondents influence their perception expressed through mapping behaviour. However, there are more similarities than differences in mapping behaviour within the sample to conclude that perception is influenced with socio-demographic characteristics. This could be due to the design of the questionnaire and the limited number of markers that could be used by respondents. However, changes were not expressed even within mapping questions where respondents could choose attributes to map. Lesser influence of socio-demographic variables on the perception of services and disservices has also been acknowledged in other research (Baumeister et al., 2022; Fagerholm et al., 2019; Garcia-Martin et al., 2017; Krajter Ostoić et al., 2017; Rall et al., 2017). Future research should put more emphasis on sampling approach and try to gather more representative sample for the area to further explore the possible differences.

5.2.14. Influence of visiting behaviour on expressed perception of cultural ecosystem services and disservices in the city of Zagreb

The second set of produced GMLs looked into the relationship between visiting and mapping behaviour of the respondents. Usual visiting patterns expressed as Visiting Frequency to green spaces influenced mapping behaviour for Place Attachment, Hiking, Walking, Aesthetic Experiences, and attributing locations as Restorative. It is interesting to state that those who visited green spaces seldom expressed less Place Attachment on the map, thus frequent visiting to green spaces indicates better human-nature relationship. Higher visiting frequency benefits people's well-being. It has already been mentioned that Biking was more mapped by men, but also it was more mapped by those who expressed frequent visiting behaviour to green spaces in Zagreb. Biking was probably the main activity of those respondents when visiting green spaces, further corresponding with the chosen locations, which are usually bike-friendly. Those respondents who expressed less frequent visiting behaviour also mapped to a lesser extent Hiking as recreational activity. This is understandable since hiking usually requires travelling to a specific location and allocating more time for the activity, and since those respondents usually infrequently visit green spaces in Zagreb, activities like hiking are probably not of primary interest to them while visiting. Furthermore, those who stated that they visited green spaces in Zagreb occasionally also perceived to lesser extent UGI as Restorative. Aesthetic Experiences in relation to stated visiting behaviour emerged with lower mapping effort for most of the visiting patterns. With regard to the aforementioned, based on a more focused research on the importance of trees in parks it was concluded that people who visit parks less frequently also put less emphasis on the importance of trees for aesthetic experiences (Collins et al., 2019).

As already mentioned within the results section, Part of the Day when the respondents visit green spaces did not significantly influence any mapping behaviour, hence there were no difference in perception. Some differences were noticeable in the results; however, none of them proved statistically important enough. Therefore, it can be concluded that part of the day as one of the visiting behaviour patterns that respondents expressed did not influence the perception neither of cultural ecosystem services nor of disservices.

Part of the Week only influenced place attachment, since those who visit green spaces on weekdays or during the whole week expressed more mapping behaviour, and more locations they regard to be favourite. For the rest of cultural ecosystem services or disservices, visiting pattern in the part of the week when respondents visit green spaces was not proven a major

influence on the perception. However, research has shown that people look for distinct characteristics of locations and express different visiting behaviour in relation to their visiting patterns, i.e., weekdays or weekends (Bertram et al., 2017).

Exploring the relationship between the stated duration of visits and mapped attributes resulted with findings that those who mapped Running stay more than two hours on average in green spaces in Zagreb. Also, those who stay more than two hours in green spaces mapped Walking to a lesser extent. This could be due to a difference in nature of these activities since walking is defined as the low-intensity activity (Brown et al., 2014) and the most popular one throughout different research and spatial and cultural context, and because everyday walks are usually not lengthy. On the other hand, running as high-intensity activity also might be practiced as a competitive activity, possibly as long-distance running or when people spend more time in green spaces in preparation for races. In the PPGIS questionnaire, Running was not defined through its duration, so this could be one explanation for this behaviour, but not the only one possible. Nevertheless, duration of staying in green spaces did not influence the perception of different cultural ecosystem services and disservices within the sample of population in this research. Also, in a Europe-wide study neither duration nor frequency of visits to parks influenced the overall satisfaction with them (Zwierzchowska et al., 2018).

Those respondents who stated that they visited green spaces primarily with their children also mapped children-related activity (Taking the Kids Out) to a higher extent than the others, which is in line with their expressed visiting behaviour. Also, those respondents mapped less Place Attachment locations, less Dog Walking activities and less Cultural Identity locations. It is interesting to mention that those who expressed visiting green spaces in company of other people more frequently mapped Walking. This is a further indication of the interrelation between the cultural ecosystem services because visiting in company is characterised with interaction among people, which can be described as a cultural ecosystem service (Vierikko et al., 2020). Those who visit green spaces in company also mapped more Socializing with others, but this relationship is not statistically significant. Apart from that, company in which the respondents visit green spaces in the city of Zagreb did not influence the perception of cultural ecosystem services or disservices to a larger extent.

Similarly, to socio-demographic variables, the visiting patterns that the respondents expressed mostly did not influence mapping behaviour understood as the perception of UGI in Zagreb. High correlation coefficients and a small number of statistically significant differences in

mapping behaviour are not enough to firmly conclude that the relationship exists. There is indication that perception can be influenced by visiting behaviour, but more aimed research on this specific topic is needed.

To sum up, even though it was hypothesised that the perception and use will be influenced by socio-demographic characteristics of the respondents and their visiting behaviour, this cannot be confirmed with results of this research. While differences exist, there are not enough of them to confirm this part of the hypothesis. However, UGI type, distance from home and urban-rural gradient influence the perception and use of UGI in Zagreb. Therefore, the second hypothesis has been partially confirmed with this research.

5.3. Reflection on the methodology applied

Temporal characteristics of cultural ecosystem services are represented in a changing environment and people's perception (Tandarić et al., 2020), but this is beyond the scope of this research. Participatory mapping when employed for defining spatial distribution of cultural ecosystem services usually results with a distribution that represents the perception people hold at that a specific time (Blicharska et al., 2017).

However, research has also shown that values people hold towards their environment are stabile over time and do not change very often, except in the case of dramatic change in that same environment (Brown et al., 2020). Based on that, 'universal' truth about places and aspects emerged as important for the perception and use of UGI in the city of Zagreb and it is also expected to be important in the future to some extent.

Successful implementation of the PPGIS questionnaire for data collection unlocked a new and tested approach to planning and management of green spaces in the city of Zagreb. This approach could be employed regardless of jurisdiction under which some green spaces are. Likewise, the presented approach does not have to be employed exclusively in urban green spaces, but rather in different protected and unprotected areas important to people where some spatially explicit information from beneficiaries and users is necessary to enhance planning and management practices.

PPGIS is a powerful toolkit for researchers and practitioners alike. Since the approach is heavily technology-based, the development of methodology and technology is still ongoing. Therefore, trade-offs occur while using this approach in scientific and professional work. Some

of the trade-offs have been well documented in scientific literature, e.g. the previously mentioned low response rate or the issues connected to the use of secondary spatial datasets for analyses. Contemporary research is ever more interested in the social-ecological research on the verge between the environment and people. There is also an ever-present need for sustainable development of cities that will help in reducing harmful consequences of climate change and will be in accordance with the adopted global and local policies. The majority of the information in today's world comprises some amount of spatial data or at least spatial context, hence spatial information is usually especially important for decision-making. That is crucial for decisions regarding ecosystem services. Ecosystem services are commonly inseparable from the perception, and if they are not perceived as beneficial or important, they would not be a part of ecosystem services framework. Allowing people to mark locations, i.e., to express the spatial component of perception, might be the framework for further research on the traits, characteristic and influence of those locations. PPGIS also presents new approach to public participation in issues related to city planning and management. Providing people with new ways of participation in public life and decision-making could enhance current practice in a way that includes those people inclined to participation, however not in a current form.

The study area for this research was the whole city of Zagreb. It is known that the extent of the study area influences the results. Locations and areas that are revealed as important in a large area study tend to be attractive even at greater distances (Tyrväinen et al., 2007). It could be argued that with research on a smaller scale, some other locally important green areas would emerge, but in such case, data generalization on a city-wide level is not recommended. Additionally, the results of a distance analysis revealed that the minimum values calculated for the majority of spatial markers are less than 100 m from the centroids representing home addresses, and thus one can argue that the respondents were quite precise with placing their spatial markers. Therefore, even on a larger scale, with respondents motivated enough, satisfactory results could be gathered. Using appropriate spatial scale and mapping design for participatory mapping results with the information that could be further used in planning and management (Kahila-Tani et al., 2019).

6. CONCLUSIONS

This study presents the first implementation of a PPGIS questionnaire for the assessment of cultural ecosystem services and disservices provided by UGI as perceived by the citizens in the city of Zagreb. This research resulted with information about how different UGI types are perceived and used on a city-level. The results provide a novel, empirical insight into the perception of different types of UGI, similarities and differences, as well as synergies and trade-offs that emerged between them. In addition, within this research comprehensive overview of different categories and attributes of cultural ecosystem services and disservices was given, along with the level of emphasis citizens of Zagreb have put on each expressed perception through mapping frequency. All of these add new and important information not only for the city of Zagreb, but also for the scientific literature where some of the information presented here were missing.

Within the questionnaire, different attributes of cultural ecosystem services and disservices have been explored and they have all been perceived to some extent, acknowledging the used methodological approach. Nevertheless, positive perception predominates the negative one, with higher mapping frequency found for attributes of Aesthetics than Disservices. Those cultural ecosystem services that are easier to perceive or use were mapped by more respondents – Place Attachment, Recreation, Aesthetics and Cultural Identity – while Education and Disservices were either less important for the respondents or harder to spatially delineate on the map of Zagreb.

Regarding UGI, parks, forests, park forests, water features but also other unmanaged green areas, along with the Botanical Garden, emerged as holders of perception and use throughout the city of Zagreb. However, a range of different UGI types that contain trees were perceived and used by the respondents, such as green areas around residential buildings and cemeteries. Differentiation in the perception has also been noticed. Parks in the city of Zagreb were perceived as green spaces providing Cultural Identity values, opportunities for Education, along with being Maintained and offering Aesthetical Experiences. On the other hand, forests were mostly connected with the perception of Naturalness, Watching Nature, and Hiking. The results also show the intertwined perception people hold toward some parts of UGI in Zagreb, where disservices and services coexist, and trade-offs occur, providing important information for planning and management of green spaces in Zagreb.

While generalization of UGI types can provide with important city-wide information, cartographic representation of the collected spatial markers provided exact locations that emerged as hotspots for each attribute explored. Maksimir Park, along with parks Bundek and Jarun, proved the importance of parks for the citizens of Zagreb, especially being providers of cultural ecosystem services with an emphasis on recreational opportunities, but also disservices. Forests, primarily on the slope of Medvednica Mountain, along with park forests, where Dotrščina and Grmoščica emerged as hotspots, are perceived as natural areas used for hiking, observing nature and as restorative places, but also as places for education and as holders of cultural identity. Likewise, hotspot maps of perceived disservices highlight locations in the city of Zagreb where different nuisances exist, possibly hindering the use of those green spaces. Produced maps like those in this research can be used as an effective approach for dissemination of gathered results towards the interested public and the city government alike. Other analyses of spatial data employed within this work, such as distance analysis or hierarchical clustering for exploring urban-rural gradient, resulted with information that was used to provide a complete overview of the perception and use of UGI in the city of Zagreb.

The PPGIS questionnaire managed to reach citizens from every city district in the city of Zagreb, despite being part of a scientific research. Citizens showed interest for the research and the questionnaire, expressed with mapping effort they put in. Still, middle-aged, highly educated, and frequent visitors to green spaces in Zagreb have been more prone to engage with the questionnaire. Socio-demographic or visiting behaviour characteristics of the respondents showed little influence on the perception and use of UGI in Zagreb. However, the gathered sample demonstrates the part of population in Zagreb that would be more inclined to engage with participation in planning, management and decision-making by utilizing spatially explicit methods.

This study also provided some results that cannot be explained within the scope of this research, and therefore new research questions were potentially opened for further continuation of research of UGI of the city of Zagreb, with this research set as a basis.

UGI is important for sustainable development of cities. Understanding how people perceive and use different types of UGI as well as the locations that emerge as hotspots help can help in planning and management practices. Acknowledging different aspects of green spaces' use and perception leads towards better and more informed decision-making that the public would embrace.

7. LITERATURE

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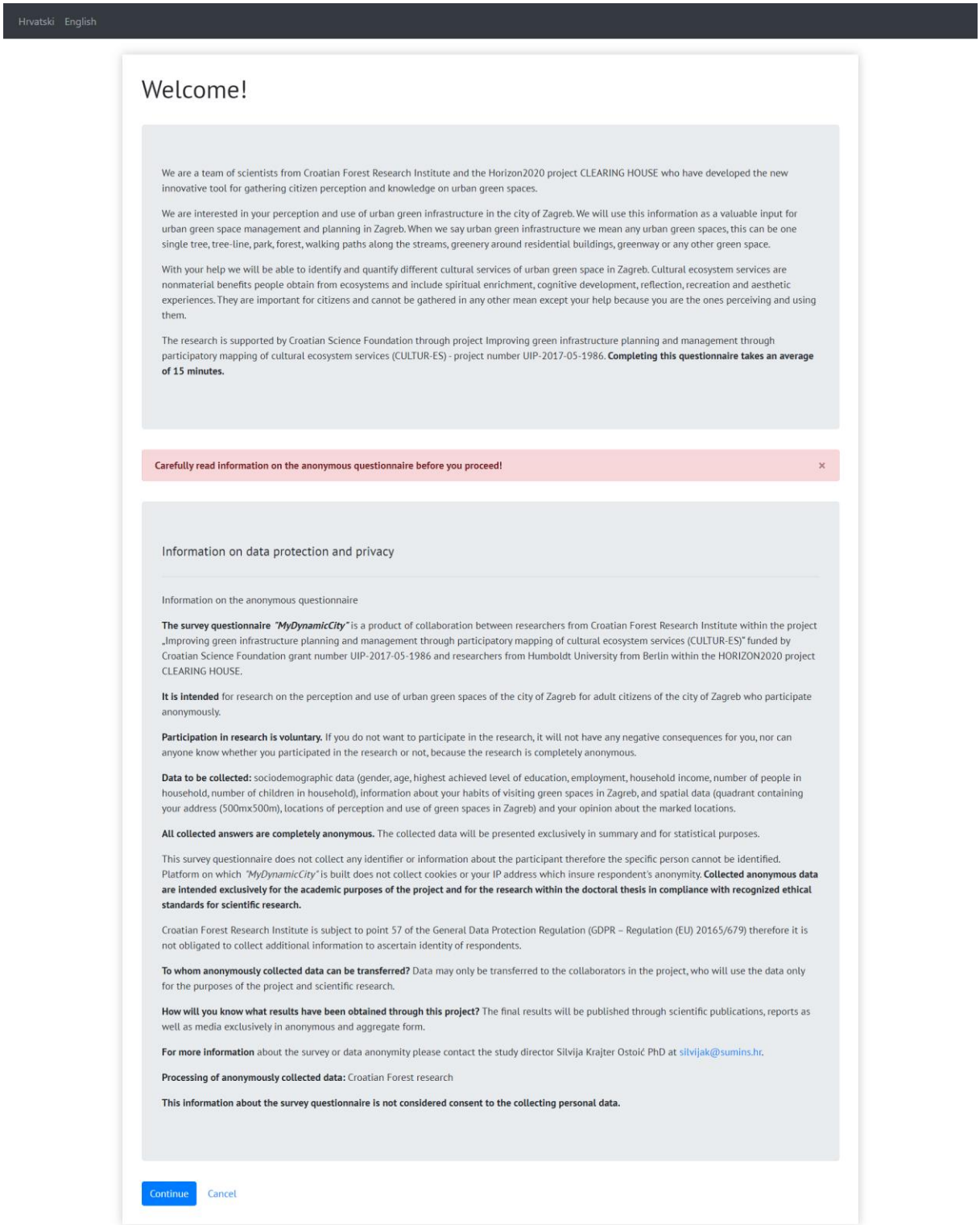
URL2: https://www.sportskiobjekti.hr/default.aspx?id=8510 [12.6.2022]

URL3: https://www.infozagreb.hr/istrazi-zagreb/atrakcije/parkovi/bundek [12.6.2022]

8. APPENDICES

Appendix 1 – PPGIS *MyDynamicCity* Zagreb questionnaire



Hrvatski English

Welcome!

We are a team of scientists from Croatian Forest Research Institute and the Horizon2020 project CLEARING HOUSE who have developed the new innovative tool for gathering citizen perception and knowledge on urban green spaces.

We are interested in your perception and use of urban green infrastructure in the city of Zagreb. We will use this information as a valuable input for urban green space management and planning in Zagreb. When we say urban green infrastructure we mean any urban green spaces, this can be one single tree, tree-line, park, forest, walking paths along the streams, greenery around residential buildings, greenway or any other green space.

With your help we will be able to identify and quantify different cultural services of urban green space in Zagreb. Cultural ecosystem services are nonmaterial benefits people obtain from ecosystems and include spiritual enrichment, cognitive development, reflection, recreation and aesthetic experiences. They are important for citizens and cannot be gathered in any other mean except your help because you are the ones perceiving and using them.

The research is supported by Croatian Science Foundation through project Improving green infrastructure planning and management through participatory mapping of cultural ecosystem services (CULTUR-ES) - project number UIP-2017-05-1986. **Completing this questionnaire takes an average of 15 minutes.**

Carefully read information on the anonymous questionnaire before you proceed! ×

Information on data protection and privacy

Information on the anonymous questionnaire

The survey questionnaire *"MyDynamicCity"* is a product of collaboration between researchers from Croatian Forest Research Institute within the project „Improving green infrastructure planning and management through participatory mapping of cultural ecosystem services (CULTUR-ES)" funded by Croatian Science Foundation grant number UIP-2017-05-1986 and researchers from Humboldt University from Berlin within the HORIZON2020 project CLEARING HOUSE.

It is intended for research on the perception and use of urban green spaces of the city of Zagreb for adult citizens of the city of Zagreb who participate anonymously.

Participation in research is voluntary. If you do not want to participate in the research, it will not have any negative consequences for you, nor can anyone know whether you participated in the research or not, because the research is completely anonymous.

Data to be collected: sociodemographic data (gender, age, highest achieved level of education, employment, household income, number of people in household, number of children in household), information about your habits of visiting green spaces in Zagreb, and spatial data (quadrant containing your address (500mx500m), locations of perception and use of green spaces in Zagreb) and your opinion about the marked locations.

All collected answers are completely anonymous. The collected data will be presented exclusively in summary and for statistical purposes.

This survey questionnaire does not collect any identifier or information about the participant therefore the specific person cannot be identified. Platform on which *"MyDynamicCity"* is built does not collect cookies or your IP address which insure respondent's anonymity. **Collected anonymous data are intended exclusively for the academic purposes of the project and for the research within the doctoral thesis in compliance with recognized ethical standards for scientific research.**

Croatian Forest Research Institute is subject to point 57 of the General Data Protection Regulation (GDPR – Regulation (EU) 20165/679) therefore it is not obligated to collect additional information to ascertain identity of respondents.

To whom anonymously collected data can be transferred? Data may only be transferred to the collaborators in the project, who will use the data only for the purposes of the project and scientific research.

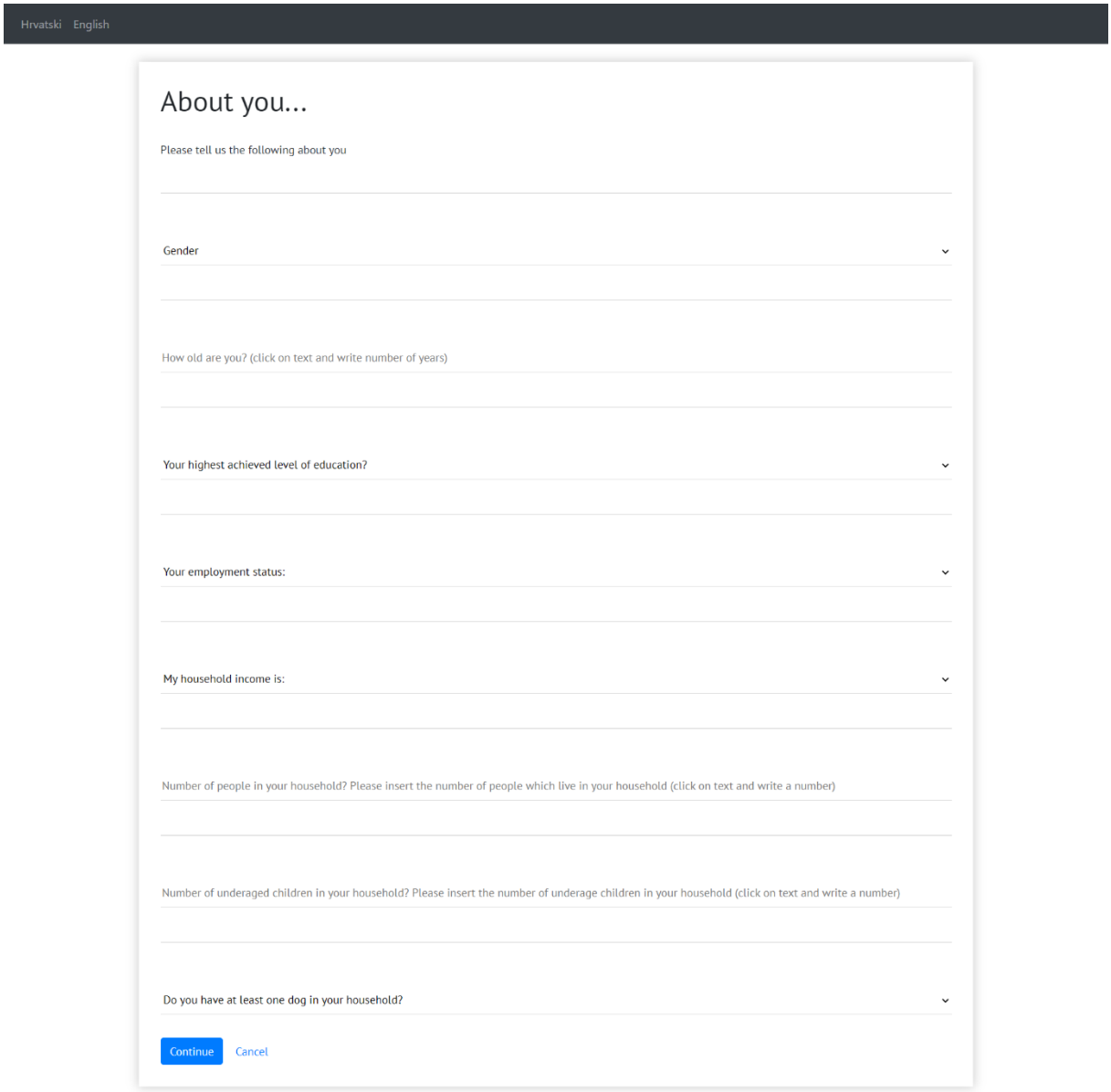
How will you know what results have been obtained through this project? The final results will be published through scientific publications, reports as well as media exclusively in anonymous and aggregate form.

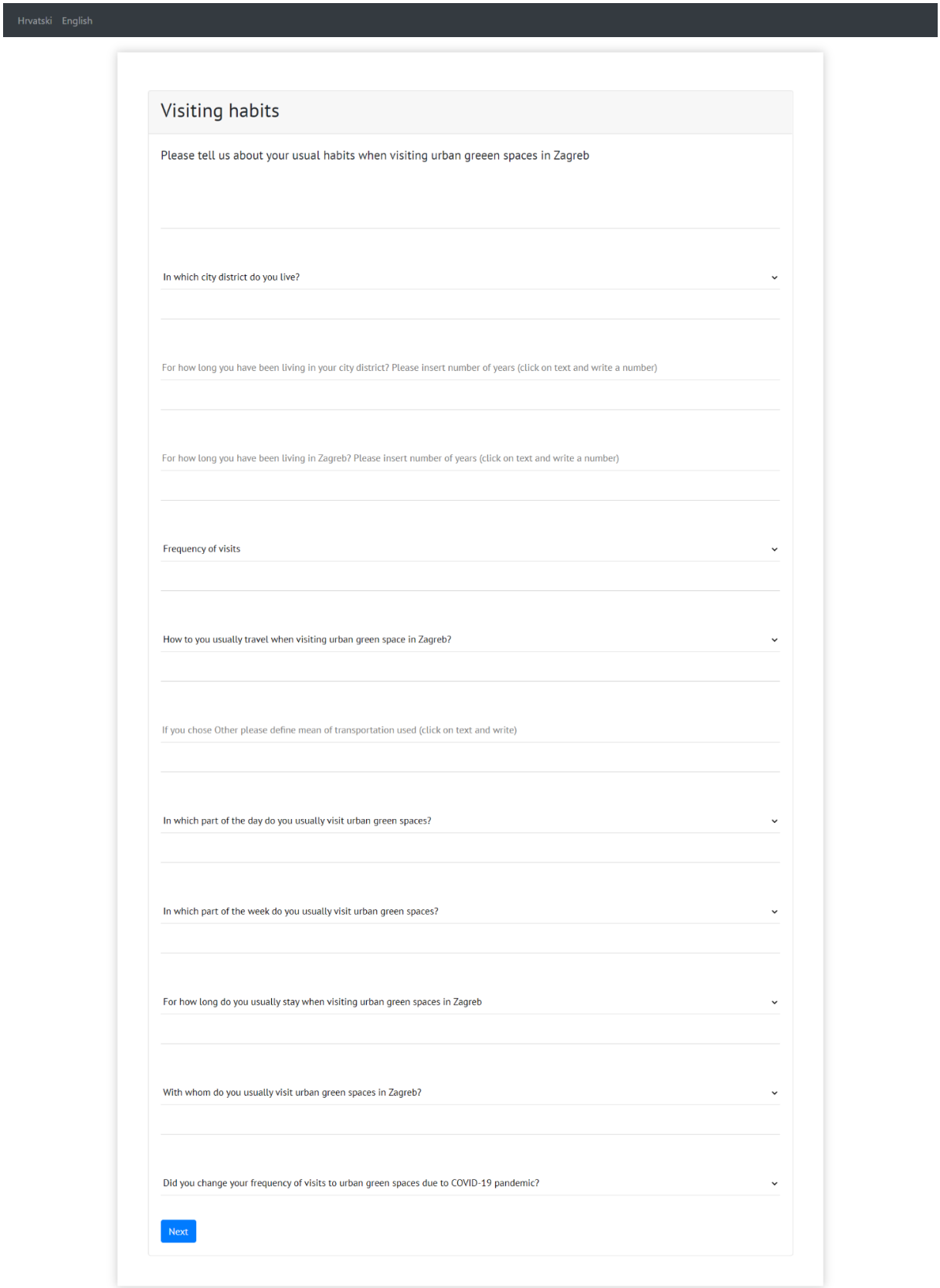
For more information about the survey or data anonymity please contact the study director Silvija Krajter Ostoić PhD at silvijak@sumins.hr.

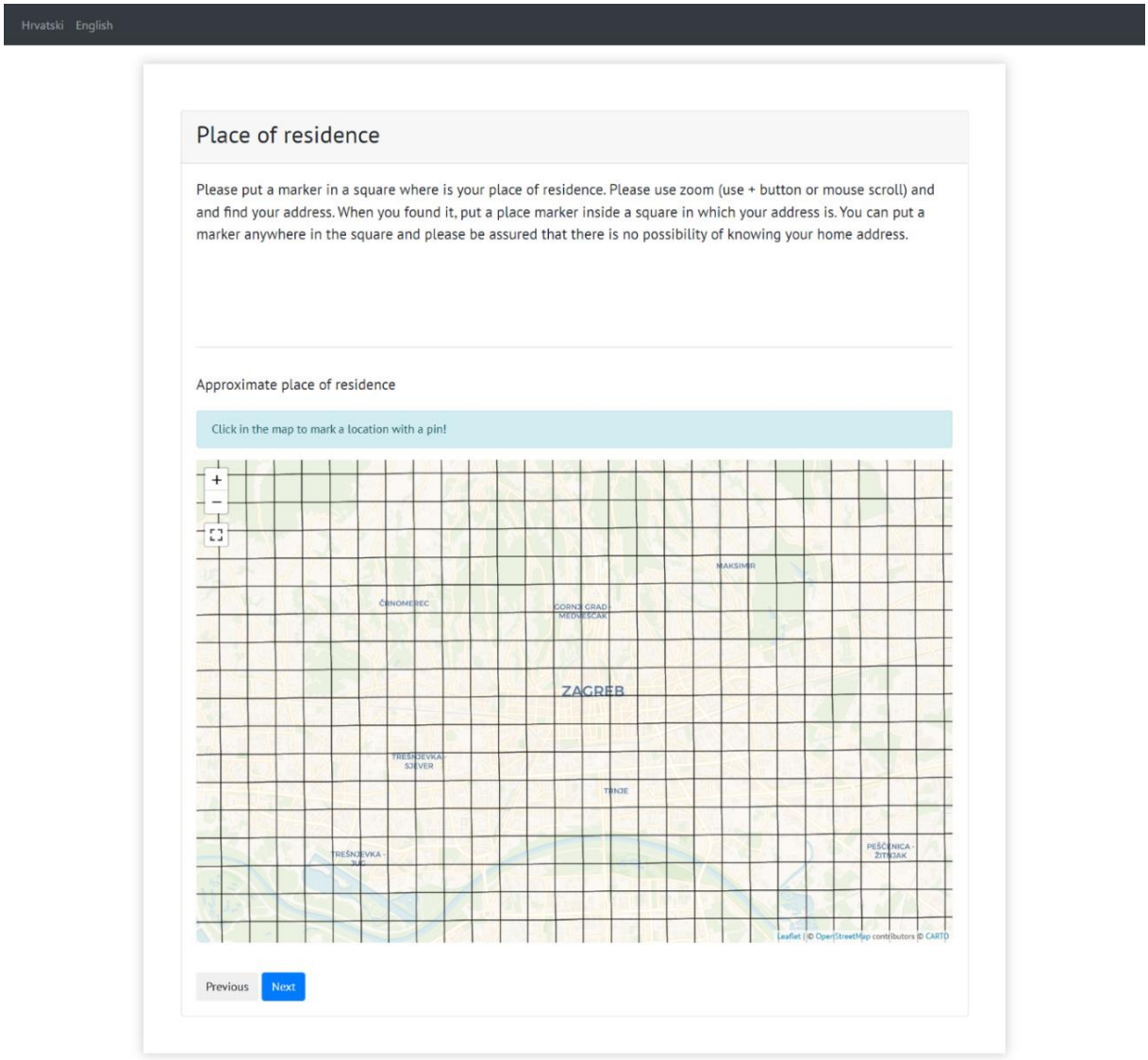
Processing of anonymously collected data: Croatian Forest research

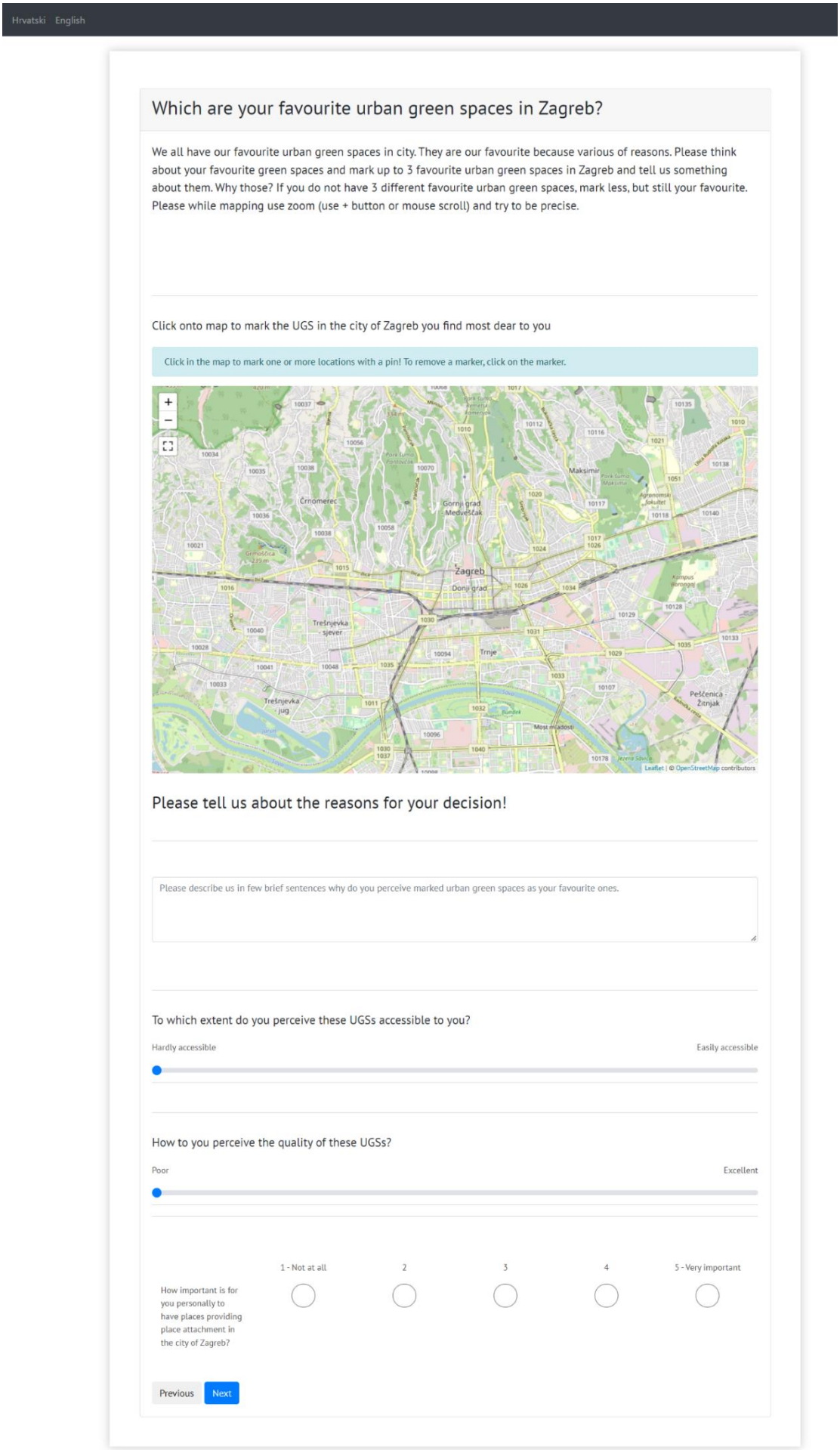
This information about the survey questionnaire is not considered consent to the collecting personal data.

Continue Cancel


Hrvatski English
About you...
Please tell us the following about you
Gender
How old are you? (click on text and write number of years)
Your highest achieved level of education?
Your employment status:
My household income is:
Number of people in your household? Please insert the number of people which live in your household (click on text and write a number)
Number of underaged children in your household? Please insert the number of underage children in your household (click on text and write a number)
Do you have at least one dog in your household?
Continue
Cancel


Hrvatski English
Visiting habits
Please tell us about your usual habits when visiting urban greeen spaces in Zagreb
In which city district do you live?
For how long you have been living in your city district? Please insert number of years (click on text and write a number)
For how long you have been living in Zagreb? Please insert number of years (click on text and write a number)
Frequency of visits
How to you usually travel when visiting urban green space in Zagreb?
If you chose Other please define mean of transportation used (click on text and write)
In which part of the day do you usually visit urban green spaces?
In which part of the week do you usually visit urban green spaces?
For how long do you usually stay when visiting urban green spaces in Zagreb
With whom do you usually visit urban green spaces in Zagreb?
Did you change your frequency of visits to urban green spaces due to COVID-19 pandemic?
Next


Hrvatski English
Place of residence
Please put a marker in a square where is your place of residence. Please use zoom (use + button or mouse scroll) and and find your address. When you found it, put a place marker inside a square in which your address is. You can put a marker anywhere in the square and please be assured that there is no possibility of knowing your home address.
Approximate place of residence
Click in the map to mark a location with a pin!
MAKSIMIR
ČRNOMEREC
GORNJI GRAD - MEDVEŠČAK
ZAGREB
TREŠNJEVKA - SJEVER
TREŠNJEVKA - JUG
TRNJE
PEŠČENICA - ŽITNJAK
Leaflet | © OpenStreetMap contributors © CARTO
Previous
Next


Hrvatski English
Which are your favourite urban green spaces in Zagreb?
We all have our favourite urban green spaces in city. They are our favourite because various of reasons. Please think about your favourite green spaces and mark up to 3 favourite urban green spaces in Zagreb and tell us something about them. Why those? If you do not have 3 different favourite urban green spaces, mark less, but still your favourite. Please while mapping use zoom (use + button or mouse scroll) and try to be precise.
Click onto map to mark the UGS in the city of Zagreb you find most dear to you
Click in the map to mark one or more locations with a pin! To remove a marker, click on the marker.
Črnomerec
Gornji grad - Medveščak
Maksimir
Zagreb
Donji grad
Trešnjevka - sjever
Trešnjevka - jug
Trnje
Peščenica - Žitnjak
Most mladosti
Leaflet | © OpenStreetMap contributors
Please tell us about the reasons for your decision!
Please describe us in few brief sentences why do you perceive marked urban green spaces as your favourite ones.
To which extent do you perceive these UGSs accessible to you?
Hardly accessible
Easily accessible
How to you perceive the quality of these UGSs?
Poor
Excellent
1 - Not at all
2
3
4
5 - Very important
How important is for you personally to have places providing place attachment in the city of Zagreb?
Previous
Next

Hrvatski English

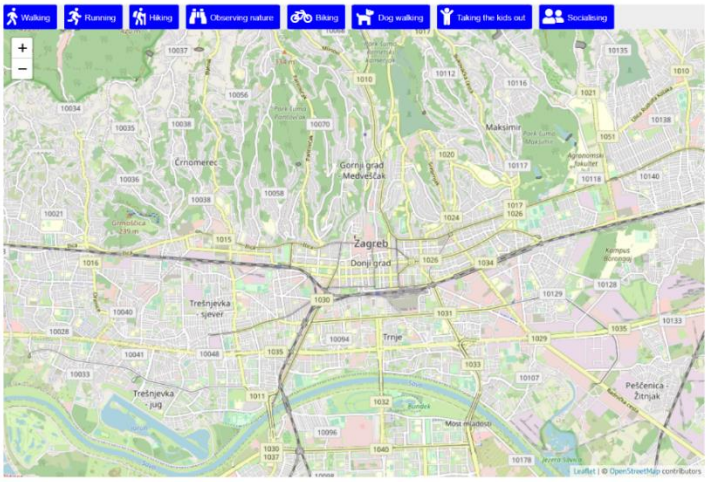
Which urban green spaces in Zagreb do you use for recreation?

Here, please think about urban green spaces in Zagreb that you use for recreation - recreation could be active (i.e. walking, running) or passive (observing nature). At maximum 3 different urban green spaces you can allocate total of 6 markers of same or different activities you undertake there. If 6 markers are too much, do not worry you can place less markers on a map. Also, if you do not use 3 different urban green spaces mark just the ones that you use. Please use zoom to be precise with your mapping.

Drag and drop icons representing activites you undertake in urban green spaces in Zagreb

Drag a marker from the bar onto the map by clicking and holding the left mouse button. Release the left mouse button to drop a marker at the desired location. Alternatively, use touch when on a supported device. A marker will be shown on to the map accordingly. Left-click a marker to remove it from the map

Walking Running Hiking Observing nature Biking Dog walking Taking the kids out Socialising



Please tell us about the reasons for your decision!

Which of the following applies to you? Pick all that apply!

Proximity | Size | Equipment (benches, trash bins, mantained paths)

To which extent do you perceive these UGSs accessible to you?

Hardly accessible — Easily accessible

How to you perceive the quality of these UGSs?

Poor — Excellent

	1 - Not at all	2	3	4	5 - Very important
How important is for you personally to have places providing recreational possibilities in the city of Zagreb?	○	○	○	○	○

Your tracks (optional)

If you track your activities in urban green spaces (i.e. track your run) and would like to help us enhance and upgrade our results you have option here to upload one of your GPS routes for us to examine

Please use one of the following file types: gpx, fit

Choose File No file chosen

If you uploaded one of your routes, please tell us what did you do (run, hike, bike or something else) (click on text and write)

Previous Next

Hrvatski English

Good and bad things of urban green spaces in Zagreb

Please think about the impression urban green spaces in Zagreb leave on you. Is it good or bad? Your impression of urban green spaces you can mark on a map by placing markers with description that you would allocated to some urban green spaces. Positive descriptions are green, and negative are red. You can combine positive and negative markers at the same urban green space. Please mark your impression of maximum 3 different urban green spaces with total of 6 markers. If you do not have impression on three different urban green spaces, mark just those spaces of which you have. Please use zoom to be precise with your mapping.

Drag and drop those markers which best represent the appearance of chosen UGS in Zagreb

Drag a marker from the bar onto the map by clicking and holding the left mouse button. Release the left mouse button to drop a marker at the desired location. Alternatively, use touch when on a supported device. A marker will be shown on to the map accordingly. Left-click a marker to remove it from the map

Please tell us about the reasons for your decision!

To which extent do you perceive these UGSs accessible to you?

Hardly accessible — Easily accessible

How to you perceive the quality of these UGSs?

Poor — Excellent

	1 - not at all	2	3	4	5 - very important
How important is for you personally to have places providing this selected good service in the city of Zagreb?	○	○	○	○	○

	1 - not at all	2	3	4	5 - very important
How important is negative perception of urban green space in your decision to use it?	○	○	○	○	○

Previous Next

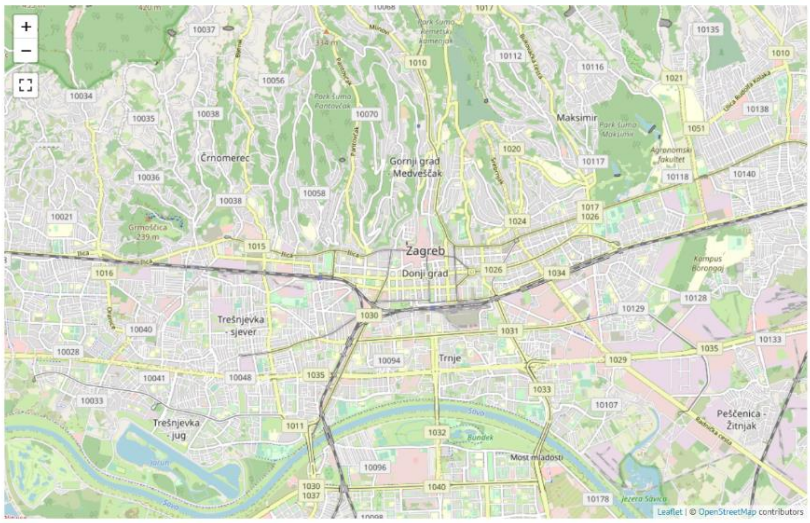
Hrvatski English

Urban green spaces in Zagreb used for Education

Please show us on a map urban green spaces that you perceive/use for educational purposes. Please note that places with educational purpose are not exclusively for children, but for all citizens of Zagreb having the opportunity to learn about nature in urban green space. Plase mark up to 3 different urban green spaces, but as before you can mark less. Please use zoom to be precise with your mapping.

Click onto map to mark the UGS you perceive as providers of education

Click in the map to mark one or more locations with a pin! To remove a marker, click on the marker.



Please tell us about the reasons for your decision!

Which of the following applies to you? Pick all that apply!

Close to educational institutions | Name tags of plant species/educational trails | Have park furniture (benches, trash bins) | Have facilities (toilets, cafe/restaurant, etc) | Have a guide/interpreter

To which extent do you perceive these UGSs accessible to you?

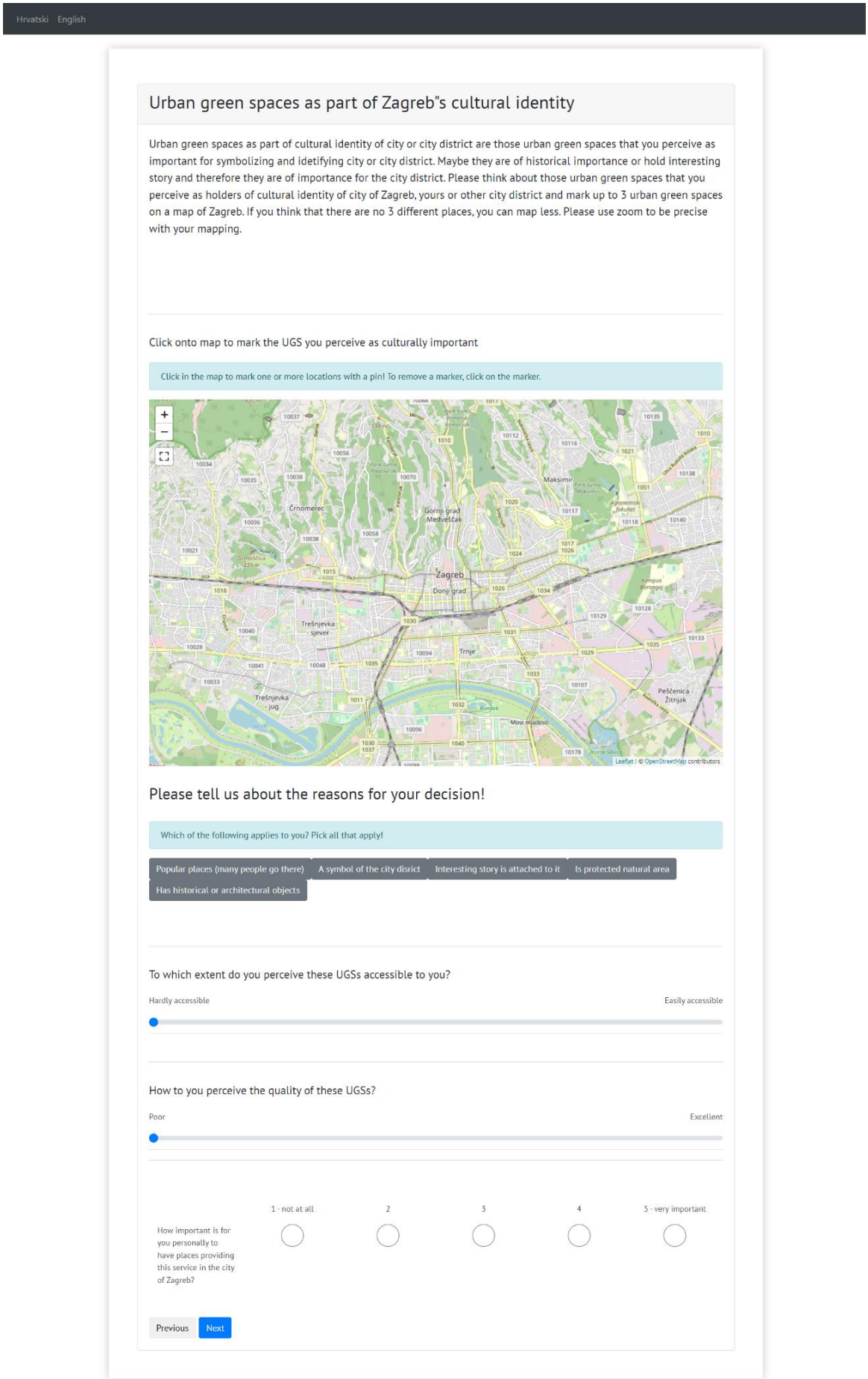
Hardly accessible — Easily accessible

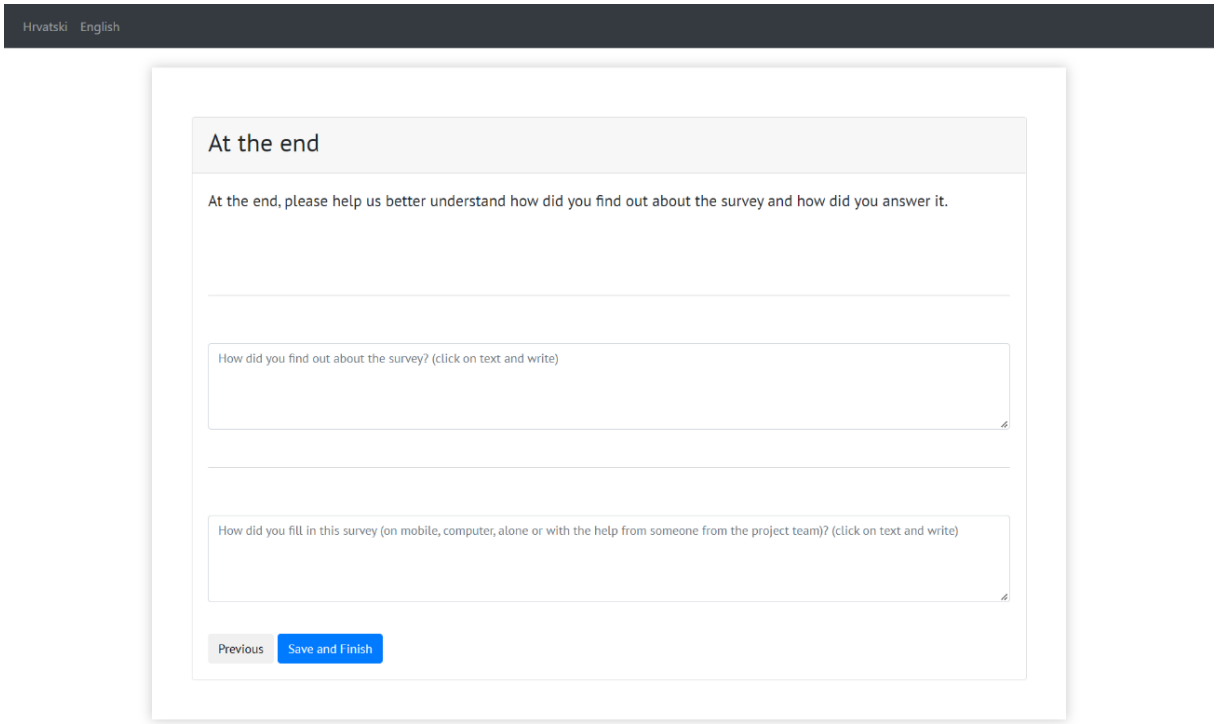
How to you perceive the quality of these UGSs?

Poor — Excellent

	1 - not at all	2	3	4	5 - very important
How important is for you personally to have places providing educational service in the city of Zagreb?	○	○	○	○	○

Previous Next


Hrvatski English
Urban green spaces as part of Zagreb"s cultural identity
Urban green spaces as part of cultural identity of city or city district are those urban green spaces that you perceive as important for symbolizing and idetifying city or city district. Maybe they are of historical importance or hold interesting story and therefore they are of importance for the city district. Please think about those urban green spaces that you perceive as holders of cultural identity of city of Zagreb, yours or other city district and mark up to 3 urban green spaces on a map of Zagreb. If you think that there are no 3 different places, you can map less. Please use zoom to be precise with your mapping.
Click onto map to mark the UGS you perceive as culturally important
Click in the map to mark one or more locations with a pin! To remove a marker, click on the marker.
Črnomerec
Gornji grad Medveščak
Maksimir
Zagreb
Donji grad
Trešnjevka sjever
Trnje
Trešnjevka - jug
Peščenica - Žitnjak
Most mladosti
Leaflet | © OpenStreetMap contributors
Please tell us about the reasons for your decision!
Which of the following applies to you? Pick all that apply!
Popular places (many people go there)
A symbol of the city disrict
Interesting story is attached to it
Is protected natural area
Has historical or architectural objects
To which extent do you perceive these UGSs accessible to you?
Hardly accessible
Easily accessible
How to you perceive the quality of these UGSs?
Poor
Excellent
1 - not at all
2
3
4
5 - very important
How important is for you personally to have places providing this service in the city of Zagreb?
Previous
Next


Hrvatski English
At the end
At the end, please help us better understand how did you find out about the survey and how did you answer it.
How did you find out about the survey? (click on text and write)
How did you fill in this survey (on mobile, computer, alone or with the help from someone from the project team)? (click on text and write)
Previous
Save and Finish

Appendix 2 – Pairwise comparison of measured distances between each CES/Disservice

Comparison	Z	P.unadj	P.adj
Place Attachment - R/Bike	-0.493	0.622	1.000
Place Attachment - R/Dog	**4.623**	**0.000**	**0.001**
Place Attachment - R/Hike	**-12.295**	**0.000**	**0.000**
Place Attachment - R/Kids	2.463	0.014	1.000
Place Attachment - R/Nature Watching	-3.285	0.001	0.175
Place Attachment - R/Run	3.719	0.000	0.034
Place Attachment - R/Social	-0.244	0.807	1.000
Place Attachment - R/Walk	0.949	0.343	1.000
R/Bike - R/Dog	**4.076**	**0.000**	**0.008**
R/Bike - R/Hike	**-9.620**	**0.000**	**0.000**
R/Bike - R/Kids	2.345	0.019	1.000
R/Bike - R/Nature Watching	-2.312	0.021	1.000
R/Bike - R/Run	3.423	0.001	0.106
R/Bike - R/Social	0.238	0.812	1.000
R/Bike - R/Walk	1.070	0.284	1.000
R/Dog - R/Hike	**-12.901**	**0.000**	**0.000**
R/Dog - R/Kids	-1.598	0.110	1.000
R/Dog - R/Nature Watching	**-5.984**	**0.000**	**0.000**
R/Dog - R/Run	-0.381	0.703	1.000
R/Dog - R/Social	**-4.162**	**0.000**	**0.005**
R/Dog - R/Walk	-3.824	0.000	0.022
R/Hike - R/Kids	**11.214**	**0.000**	**0.000**
R/Hike - R/Nature Watching	**6.820**	**0.000**	**0.000**
R/Hike - R/Run	**11.824**	**0.000**	**0.000**
R/Hike - R/Social	**10.538**	**0.000**	**0.000**
R/Hike - R/Walk	**12.219**	**0.000**	**0.000**
R/Kids - R/Nature Watching	**-4.357**	**0.000**	**0.002**
R/Kids - R/Run	1.133	0.257	1.000
R/Kids - R/Social	-2.300	0.021	1.000
R/Kids - R/Walk	-1.789	0.074	1.000
R/Nature Watching - R/Run	**5.283**	**0.000**	**0.000**
R/Nature Watching - R/Social	2.698	0.007	1.000
R/Nature Watching - R/Walk	3.663	0.000	0.043
R/Run - R/Social	-3.442	0.001	0.099
R/Run - R/Walk	-3.046	0.002	0.397
R/Social - R/Walk	0.915	0.360	1000
A/Experiences - Place Attachment	1.651	0.099	1.000
A/Experiences - R/Bike	0.776	0.438	1.000
A/Experiences - R/Dog	**5.117**	**0.000**	**0.000**
A/Experiences - R/Kids	3.238	0.001	0.206
A/Experiences - R/Hike	**-9.648**	**0.000**	**0.000**
A/Experiences - R/Nature Watching	-1.782	0.075	1.000
A/Experiences - R/Run	**4.326**	**0.000**	**0.003**
A/Experiences - R/Social	1.123	0.261	1.000

A/Experiences - R/Walk	2.208	0.027	1.000
A/Experiences - A/Maintained	1.507	0.132	1.000
A/Experiences - A/Naturalness	-2.693	0.007	1.000
A/Experiences - A/Restorative	-0.625	0.532	1.000
A/Experiences - D/Conflicts	1.230	0.219	1.000
A/Experiences - D/Noisy	2.099	0.036	1.000
A/Experiences - D/Scary	2.445	0.014	1.000
A/Experiences - D/Unmaintained	**5.500**	**0.000**	**0.000**
A/Experiences - Education	**-4.566**	**0.000**	**0.001**
A/Experiences - Cultural Identity	-2.958	0.003	0.529
A/Maintained - Place Attachment	-0.216	0.829	1.000
A/Maintained - R/Bike	-0.574	0.566	1.000
A/Maintained - R/Dog	3.885	0.000	0.017
A/Maintained - R/Hike	**-10.920**	**0.000**	**0.000**
A/Maintained - R/Kids	2.012	0.044	1.000
A/Maintained - R/Nature Watching	-3.021	0.003	0.431
A/Maintained - R/Run	3.178	0.001	0.254
A/Maintained - R/Social	-0.370	0.712	1.000
A/Maintained - R/Walk	0.504	0.615	1.000
A/Maintained - A/Naturalness	**-4.329**	**0.000**	**0.003**
A/Maintained - A/Restorative	-2.234	0.026	1.000
A/Maintained - D/Conflicts	0.648	0.517	1.000
A/Maintained - D/Noisy	0.949	0.343	1.000
A/Maintained - D/Scary	1.653	0.098	1.000
A/Maintained - D/Unmaintained	**4.258**	**0.000**	**0.004**
A/Maintained - Education	**-6.434**	**0.000**	**0.000**
A/Maintained – Cultural Identity	**-4.849**	**0.000**	**0.000**
A/Naturalness – Place Attachment	**5.344**	**0.000**	**0.000**
A/Naturalness - R/Bike	3.208	0.001	0.229
A/Naturalness - R/Dog	**7.561**	**0.000**	**0.000**
A/Naturalness - R/Hike	**-7.941**	**0.000**	**0.000**
A/Naturalness - R/Kids	**5.559**	**0.000**	**0.000**
A/Naturalness - R/Nature Watching	0.287	0.774	1.000
A/Naturalness - R/Social	3.881	0.000	0.018
A/Naturalness - R/Run	**6.531**	**0.000**	**0.000**
A/Naturalness - R/Walk	**5.562**	**0.000**	**0.000**
A/Naturalness - A/Restorative	2.213	0.027	1.000
A/Naturalness - D/Conflicts	2.231	0.026	1.000
A/Naturalness - D/Noisy	**4.198**	**0.000**	**0.005**
A/Naturalness - D/Scary	3.850	0.000	0.020
A/Naturalness - D/Unmaintained	**7.988**	**0.000**	**0.000**
A/Naturalness - Education	-1.701	0.089	1.000
A/Naturalness – Cultural Identity	0.151	0.880	1.000
A/Restorative - Place Attachment	2.629	0.009	1.000
A/Restorative - R/Bike	1.370	0.171	1.000
A/Restorative - R/Dog	**5.847**	**0.000**	**0.000**
A/Restorative - R/Hike	**-9.541**	**0.000**	**0.000**

A/Restorative - R/Kids	3.878	0.000	0.018
A/Restorative - R/Nature Watching	-1.354	0.176	1.000
A/Restorative - R/Run	**4.956**	**0.000**	**0.000**
A/Restorative - R/Social	1.815	0.069	1.000
A/Restorative - R/Walk	3.122	0.002	0.307
A/Restorative - D/Conflicts	1.472	0.141	1.000
A/Restorative - D/Noisy	2.644	0.008	1.000
A/Restorative - D/Scary	2.803	0.005	0.865
A/Restorative - D/Unmaintained	**6.255**	**0.000**	**0.000**
A/Restorative - Education	**-4.226**	**0.000**	**0.004**
A/Restorative - Cultural Identity	-2.458	0.014	1.000
D/Conflicts - Place Attachment	-0.734	0.463	1.000
D/Conflicts - R/Bike	-0.879	0.380	1.000
D/Conflicts - R/Dog	1.123	0.262	1.000
D/Conflicts - R/Hike	**-5.615**	**0.000**	**0.000**
D/Conflicts - R/Kids	0.289	0.772	1.000
D/Conflicts - R/Nature Watching	-2.005	0.045	1.000
D/Conflicts - R/Social	-0.790	0.429	1.000
D/Conflicts - R/Run	0.900	0.368	1.000
D/Conflicts - R/Walk	-0.485	0.628	1.000
D/Conflicts - D/Noisy	-0.161	0.872	1.000
D/Conflicts - D/Scary	0.478	0.633	1.000
D/Conflicts - D/Unmaintained	1.276	0.202	1.000
D/Conflicts - Education	-2.771	0.006	0.957
D/Noisy - Place Attachment	-1.213	0.225	1.000
D/Noisy - R/Bike	-1.343	0.179	1.000
D/Noisy - R/Dog	2.340	0.019	1.000
D/Noisy - R/Kids	0.819	0.413	1.000
D/Noisy - R/Nature Watching	-3.322	0.001	0.153
D/Noisy - R/Hike	**-9.832**	**0.000**	**0.000**
D/Noisy - R/Social	-1.226	0.220	1.000
D/Noisy - R/Run	1.864	0.062	1.000
D/Noisy - R/Walk	-0.655	0.513	1.000
D/Noisy - D/Scary	0.913	0.361	1.000
D/Noisy - D/Unmaintained	2.630	0.009	1.000
D/Noisy - Education	**-5.556**	**0.000**	**0.000**
D/Scary - Place Attachment	-1.835	0.066	1.000
D/Scary - R/Bike	-1.924	0.054	1.000
D/Scary - R/Dog	0.767	0.443	1.000
D/Scary - R/Hike	**-8.157**	**0.000**	**0.000**
D/Scary - R/Kids	-0.338	0.736	1.000
D/Scary - R/Nature Watching	-3.375	0.001	0.126
D/Scary - R/Run	0.477	0.633	1.000
D/Scary - R/Social	-1.843	0.065	1.000
D/Scary - R/Walk	-1.466	0.143	1.000
D/Scary - D/Unmaintained	0.970	0.332	1.000
D/Scary - Education	**-4.665**	**0.000**	**0.001**

D/Unmaintained - Place Attachment	**-5.068**	**0.000**	**0.000**
D/Unmaintained - R/Bike	**-4.418**	**0.000**	**0.002**
D/Unmaintained - R/Dog	-0.294	0.769	1.000
D/Unmaintained - R/Hike	**-13.277**	**0.000**	**0.000**
D/Unmaintained - R/Kids	-1.900	0.057	1.000
D/Unmaintained - R/Nature Watching	**-6.313**	**0.000**	**0.000**
D/Unmaintained - R/Run	-0.660	0.509	1.000
D/Unmaintained - R/Social	**-4.535**	**0.000**	**0.001**
D/Unmaintained - R/Walk	**-4.233**	**0.000**	**0.004**
D/Unmaintained - Education	**-9.846**	**0.000**	**0.000**
Education – Place Attachment	**8.877**	**0.000**	**0.000**
Education - R/Bike	**4.837**	**0.000**	**0.000**
Education - R/Dog	**9.357**	**0.000**	**0.000**
Education - R/Hike	**-7.371**	**0.000**	**0.000**
Education - R/Kids	**7.167**	**0.000**	**0.000**
Education - R/Nature Watching	1.479	0.139	1.000
Education - R/Run	**8.056**	**0.000**	**0.000**
Education - R/Social	**5.888**	**0.000**	**0.000**
Education - R/Walk	**8.479**	**0.000**	**0.000**
Cultural Identity – Place Attachment	**6.756**	**0.000**	**0.000**
Cultural Identity - R/Bike	3.450	0.001	0.096
Cultural Identity - R/Dog	**8.152**	**0.000**	**0.000**
Cultural Identity - R/Hike	**-8.742**	**0.000**	**0.000**
Cultural Identity - R/Kids	**5.953**	**0.000**	**0.000**
Cultural Identity - R/Nature Watching	0.210	0.834	1.000
Cultural Identity - R/Run	**6.938**	**0.000**	**0.000**
Cultural Identity - R/Social	**4.317**	**0.000**	**0.003**
Cultural Identity - R/Walk	**6.630**	**0.000**	**0.000**
Cultural Identity - D/Conflicts	2.224	0.026	1.000
Cultural Identity - D/Noisy	**4.421**	**0.000**	**0.002**
Cultural Identity - D/Scary	3.914	0.000	0.016
Cultural Identity - D/Unmaintained	**8.635**	**0.000**	**0.000**
Cultural Identity - Education	-2346	0.019	1.000

Appendix 3 – Contingency table of the collected spatial markers in each city district by cultural ecosystem service or disservice attributes

CES/Disservice City District	PA	R/Bike	R/Dog	R/Hike	R/Kids	R/NW	R/Run	R/Soc	R/Wlk	A/Exp	A/Main	A/Nat	A/Rest	D/Conf	D/Noisy	D/Scary	D/Unm	EDU	CI
Brezovica	6	2	3	0	1	2	1	1	2	1	1	2	1	0	0	1	1	0	3
Črnomerec	55	5	12	20	7	11	4	9	25	9	8	32	25	3	4	3	17	43	35
Donja Dubrava	2	0	0	1	1	0	0	2	0	1	1	0	0	0	2	0	1	0	2
Donji Grad	72	1	6	0	2	7	2	25	17	40	34	9	12	0	28	3	5	74	198
Gornja Dubrava	21	4	3	4	3	4	6	10	15	2	2	9	4	0	1	0	6	17	10
Gornji Grad - Medveščak	77	2	13	0	9	6	3	20	35	17	15	24	24	1	2	5	8	68	154
Maksimir	200	34	30	1	37	38	27	55	131	80	85	104	95	4	16	5	15	215	212
Novi Zagreb - istok	103	16	14	1	14	3	6	40	50	36	48	15	23	1	11	4	6	42	48
Novi Zagreb - zapad	28	9	7	0	4	2	10	9	19	6	3	7	9	0	4	5	10	17	16
Peščenica - Žitnjak	21	3	7	0	2	6	4	3	6	2	1	11	12	1	5	4	15	30	6
Podsljeme	117	21	19	86	12	30	14	21	65	28	22	87	58	0	2	4	8	123	59
Podsused Vrapče	41	5	9	10	5	9	3	5	19	4	4	18	10	2	2	4	11	22	12
Sesvete	59	15	7	14	14	15	6	23	42	12	7	34	26	0	3	2	13	16	9
Stenjevec	7	0	1	0	0	0	1	1	5	0	5	1	4	0	0	2	2	3	1
Trešnjevka - jug	82	52	4	0	13	4	15	30	38	24	33	12	31	6	27	1	21	50	62
Trešnjevka - sjever	12	0	2	0	4	0	3	2	6	1	4	1	4	1	2	1	7	4	6
Trnje	33	16	8	0	11	1	10	12	31	8	9	2	15	3	7	1	4	9	18

Curriculum vitae / Životopis

Martina Kičić was born in Zagreb on 4th December 1993. She started her studies at the Faculty of Forestry at the University in Zagreb in 2012, and in 2017 she obtained the title Master of Urban Forestry, Nature Conservation and Environmental Protection. In 2017 she also got the Dean's award at the Faculty of Forestry for outstanding success in the academic year 2016/2017.

Since September 2018 she has been working as a research assistant at the Department for International Scientific Cooperation in Southeast Europe – EFISEE and as s PhD Student on the project 'Improving green infrastructure planning and management through participatory mapping of cultural ecosystem services (CULTUR-ES)' funded by Croatian Science Foundation. In the academic year 2018/2019 she enrolled in a postgraduate PhD study in Forestry and Wood Sciences at the Faculty of Forestry at the University of Zagreb. During her PhD she attended several summer schools and training. In 2019 she attended Trans-Atlantic Training (*Radar and Optical Remote Sensing in the Agricultural and Environmental Monitoring*) in Novi Sad, Serbia and '*LIFEGENMON, EVOLTREE summer school on scientific writing, reviewing and publishing*' in Pokljuka, Slovenia. In 2021 she attended ReNature 2nd Interdisciplinary Training School (*Planning Nature-based Solutions in Cities*). The same year she enrolled in Summer School at University College London studying *Urban Environmental Politics* and she also spent one month at Humboldt Univerizität zu Berlin in Germany.

As an author or co-author, she published 8 scientific papers. She actively participated at 8 international and 3 national scientific conferences. At Natural resources, green technology & sustainable development GREEN/4 conference she was awarded with Best Student Presentation award.

She is a member of the Croatian Forestry Society, Savate club Kraljevec, Hiking Association Alfa & Omega and Hiking Association Šumar.

Životopis

Martina Kičić rođena je 4. prosinca 1993. godine u Zagrebu. Šumarski fakultet Sveučilišta u Zagrebu upisala je 2012., a 2017. godine i diplomirala na smjeru Urbano šumarstvo, zaštita prirode i okoliša. Iste godine dobila je i Dekanovu nagradu za zapažen uspjeh u akademskoj godini 2016/2017.

U rujnu 2018. godine zapošljava se na Hrvatskom šumarskom institutu kao asistentica na Zavodu za međunarodnu znanstvenu suradnju jugoistočne Europe – EFISEE ujedno i doktorandica na projektu Hrvatske zaklade za znanost „Unaprjeđenje planiranja i gospodarenja zelenom infrastrukturom kroz participativno mapiranje kulturnih usluga ekosustava (CULTUR-ES)“. Akademske godine 2018/2019 upisuje poslijediplomski doktorski studij Šumarstvo i drvna tehnologija na Šumarskom fakultetu Sveučilišta u Zagrebu. Tijekom poslijediplomskog doktorskog studija sudjelovala na je više ljetnih škola i treninga. U 2019. godini sudjelovala je na Trans-Atlantic Trainingu (*Radar and Optical Remote Sensing in the Agricultural and Environmental Monitoring*) u Novom Sadu u Srbiji te na ljetnoj školi „*LIFEGENMON, EVOLTREE summer school on scientific writing, reviewing and publishing*“ u Pokljuki u Sloveniji. 2021. godine sudjeluje na ReNature 2nd Interdisciplinary Training School (*Planning Nature-based Solutions in Cities*). Iste godine na University College London sudjeluje na ljetnoj školi pohađajući kolegij *Urban Environmental Politics*, te odlazi i na usavršavanje u trajanju od 1 mjeseca na Humboldtovo sveučilište u Berlinu u Njemačkoj.

Do sada je u autorstvu ili koatorstvu objavila 8 znanstvenih radova. Aktivno je sudjelovala je na 8 međunarodnih i 3 domaća znanstvena skupa. Na Natural resources, green technology & sustainable development GREEN/4 konferenciji nagrađena je Best Student Presentation nagradom.

Članica je Hrvatskog šumarskog društva, Savate kluba Kraljevec, Planinarske udruge Alfa & Omega te Planinarskog društva Šumar.

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