

# Community Ecosystem Services Values Support Conservation and Sustainable Land Development: Perspectives From Four University of California Campuses

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**Keywords:** green stormwater infrastructure, nature-based solutions, ecosystem services,  
sustainable development, conservation

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## **ABSTRACT**

Since 1868, the University of California (UC) system has maintained ecological reserves adjacent to university campuses that preserve native landscape elements and provide ecosystem services to campus communities. Campuses also support other landscape forms, including ornamental gardens, turf grass lawns, and (more recently) nature-based solutions (NbS) for stormwater management that feature native vegetation. The co-existence of these landscape forms, and their high degree of accessibility to campus communities is relatively uncommon, and sets up a kind of natural experiment where the ecosystem services valued by campus communities can be compared to the services different landscapes are perceived to provide, to identify landscapes people feel matter most. We focus our efforts on the degree to which native landscape conservation and sustainable land development (i.e., implementation of NbS or replacement of lawns with native plants) are supported by the ecosystem service values of campus communities. Both strategies have been proposed as ways to connect people to wild nature in increasingly homogenized urban spaces and could have lasting impact on people and wildlife. Our work makes use of human subjects surveys conducted in 2018 at four UC campuses (734 participants total). Results from these surveys illustrate that conservation of ecological reserves (particularly coastal sage scrub) is well supported by the ecosystem services values on campus, as is replacement of lawns with native plants. Support for NbS was more variable, which likely reflects their relative newness, both on campus and in urban spaces more generally.

***Keywords:*** green stormwater infrastructure, nature-based solutions, ecosystem services, sustainable development, conservation

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## **GENERAL AUDIENCE ABSTRACT**

Since 1868, the University of California system has effectively maintained nature reserves next to each university campus that protect native landscape elements and provide ecosystem benefits to campus communities. University campuses also support other landscape forms, including decorative landscapes such as gardens and turf grass lawns, and (more recently) natural treatment systems for handling excesses of stormwater that feature native plantings that are used to slow water down or capture it. The co-existence of these landscape elements (natural, exotic ornamental, turf, and man-made), and their high degree of accessibility to campus populations is uncommon and sets up a kind of natural experiment where the benefits provided valued by campus communities can be compared to the benefits perceived to be provided by various types of landscape elements to find landscapes people feel have high value and might be strongly favored for in the future development of land. We are interested in the degree to which the protection of native landscapes and sustainable land development on campus (i.e., replacing decorative lawn with native plants or nature-based solutions for urban stormwater) are supported by the ecosystem benefits values of campus populations. Our work addresses both of these topics using a series of human subjects surveys of university students and staff conducted in 2018 at four University of California campuses (734 participants total). Our results indicate that protection of nature reserves (particularly sage scrub) is favored by campus populations as is replacement of lawns with native plants. Support for nature-based solutions was more variable.

## DEDICATION

I would like to dedicate this thesis to the love of my life, Shuvanon. Your strength and resilience in the face of adversity inspires me every day. I don't know where I would be without your love and support.

I would also like to dedicate this to my parents, Ann and Michael, and my brother, Michael, for your constant support throughout my academic career and life.

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## 1. INTRODUCTION

Over 80% of the U.S. population presently resides in urban areas (**McKinney, 2006**) and growth of these areas has accelerated far faster than efforts to conserve native landscapes in parks or nature reserves (**McKinney, 2002**). The result has been extensive loss of natural lands and associated plant and animal biodiversity; native prairie cover in Iowa has dropped from 85% to 0.1%, native grassland cover in Illinois has dropped from 60% to 0.04%, and roughly 85-96% of native sage scrub cover in California has been lost in the past 75 years, converted to urban and agricultural uses (**Miller, 2006, Taylor, 2005**).

Unfortunately, urban and agricultural landscapes are often more homogenous than the native ecosystems they replace (**McKinney, 2006, Grimm et al., 2008, Groffman et al., 2014, Wheeler et al., 2017, Haan et al., 2021**). Residential lawns are an excellent case in point. Lawns contribute to ecological homogenization at a continental scale by fostering similar ecosystems in vastly different climate zones (**Groffman et al., 2014, McKinney, 2006, Wheeler, 2017**).

Locally, their impact on biodiversity loss is relatively small; indeed, lawns can even increase biodiversity in certain regions (**Wheeler, 2017**). At larger scales, however, they exhibit a degree of species overlap that far exceeds native ecosystems (**McKinney, 2006, Wheeler, 2017**). This effect has also been observed in other urban greenspace (e.g., ornamental gardens), which may be locally biodiverse but broadly similar region to region due to preferences for (and commercial availability of) a relatively limited suite of common exotic species (**Pincetl et al., 2019**). The net result is a form of biodiversity loss that is hard to detect at the local level and that results in people feeling more connected to other urban landscapes far from home than the native ecosystems that once made up their own backyards.

The impact that urban homogenization has on people's experiences with, and perceptions

of, native landscapes has been referred to by some as “an extinction of experience”, drawing a direct parallel between the permanent loss of native ecosystem biodiversity that occurs as our world urbanizes and the disconnection between humans and natural landscapes that causes, and is caused by, it (**Pyle, 1978, Miller, 2006**). Two main approaches have been proposed to combat extinction of experience: 1) ecosystem conservation (i.e., preserving native ecosystem remnants, restoring degraded habitat, and establishing reserves so that high quality nature is protected and available to be encountered and appreciated by people), and 2) reconciliation ecology, which aims to reconcile the needs of humans and native species in urban areas through sustainable land development practices that create greenway networks and buffer existing reserves (**Rosenzweig, 2003, Miller, 2006**). The former has been used extensively and successfully in areas like Chicago, which has protected over 250,000 ha of prairies, savanna, wetlands, and forests in regional nature reserves (**Miller, 2006**) and in states like Alaska, New Jersey, and California, which allocate 39.4%, 20.1%, and 19.7% of their total available land, respectively, to parks and wildlife areas (**USDA, 2012**). This said, at present only 24% of earth’s area is protected (goal of 30% by 2030; CBD, 2020), 1/3 of crucial biodiversity areas remain unprotected (**UNEP-WCMC and IUCN, 2021**), and 24% of earth’s ecoregions have limited natural habitat remaining to protect (**Dinerstein et al., 2017**). Challenges such as these have raised the profile of conservation alternatives like reconciliation ecology in recent years (**Miller, 2006**).

While reconciliation ecology has many tools available to it, the rapid increase in green infrastructure approaches (also called nature-based solutions; NbS, **Fletcher et al., 2015, Matsler et al., 2021**) over the past 10-15 years (**McPhillips and Matsler, 2018**), has made them a cornerstone of reconciliation ecology. NbS make use of natural ecological principles to perform services that benefit people and nature, such as urban cooling, water quality services,

hydrologic services, biodiversity, and pollination (**Askarizadeh et al., 2015, Walsh et al., 2016, Portner et al., 2021, Rippy et al., 2022**). Many cities are in the process, or have already begun implementing, large-scale NbS programs, including Melbourne, AU (**Wong and Brown, 2009**), Singapore (**Lim and Lu, 2016**), Ningbo City, CN (**Griffiths et al., 2020**), Philadelphia, US (**McGarity et al., 2015**), Chicago, US (**Ando et al., 2020**), New York, US (**Miller and Montalto, 2019**), and Portland, US (**Church, 2015**), among others. Emphasis is often placed on the spatial arrangement of NbS elements, creating connected biological corridors, greener cities with higher aesthetic value, buffer zones to reduce flooding or protect natural preserves, and regions of high infiltration to reduce surface runoff and restore depleted groundwater, among other considerations (**Walsh et al., 2016, Kim and Tran, 2018, NRC, 2019, Meenar, 2019, Feagin et al., 2021**).

In more recent years, attention has increasingly been paid to the design of NbS themselves, as ecosystems; for instance, current design manuals often advocate native plant species over naturalized exotics for use in NbS (**Krauss and Rippy, 2022**). Native plants can be expected to increase the ability of NbS to serve wildlife (e.g., as habitat, refuge, or forage; **Berthon et al., 2021**) and may also help address “extinction of experience” in urban areas supposing they evoke native ecosystems to people. Because NbS are still an emerging design concept (**Adem Esmail & Suleiman, 2020, Ando et al., 2020**), however, direct comparisons between perceptions of NbS and native ecosystems remain relatively rare (**Rippy et al., 2022, Nastran et al., 2022**). This makes their utility for addressing “extinction of experience” an open question.

Another tool in the reconciliation ecology toolbox that bears specific mention here because it directly combats the greenspace type most frequently associated with urban

homogenization (and therefore “extinction of experience”), is turf replacement programs. Turf replacement programs (also called cash for grass programs) provide a monetary incentive to replace manicured lawns with alternative, low water use options, often native plants (**Jessup and DeShazo, 2016, Pincetl et al., 2019, Grant et al., 2020**). Turf replacement programs are relatively common in Mediterranean, semi-arid, and arid climates, having been implemented in Mesa, AZ, Las Vegas, NV, Austin, TX, Albuquerque, NM, as well as several counties in California (**Addink, 2005, Sovocool et al., 2006, Hollis, 2014, Pincetl et al., 2019, Grant et al., 2020**). Such programs can have large impacts on both lawn and native plant cover. For instance, it is estimated that Los Angeles County replaced 139,000 square meters of turf over a 6-year period between 2009 and 2015 (**Jessup and DeShazo, 2016**), and that approximately 14% of people that replaced turf did so with native California plant species (**Pincetl et al., 2019**). More dramatic landscape transformations are planned for Las Vegas, NV, which recently outlawed all nonfunctional (decorative) turf. Around 16 million square meters of turf is slated to be replaced with water conserving alternative landscaping by the year 2027 (SNWA, 2021). Programs like these operate at large enough scales to meaningfully change people’s exposure to native plant communities, which is necessary to foster new planting norms and develop the kind of ecological aesthetic necessary to combat extinction of experience (i.e., one where perceptions of ecological quality underlie perceptions of aesthetic quality; **Gobster et al., 2007, Nassauer et al., 2009**). This said, present support for turf replacement varies widely and isn’t limited to replacement with native plants (**Francis, 2018, Pincetl et al., 2019**), making the ultimate effect of such programs on how native ecosystems are perceived, uncertain.

In order to understand how ecosystem conservation or reconciliation ecology ultimately influence native landscape perceptions we must first characterize and compare perceptions of

native ecosystem remnants to those of common urban landscape types such as lawns, ornamental gardens and NbS, improving our understanding of how these landscapes are valued and what those values imply for future land development. Our study aims to do exactly this, focusing on a self-contained form of urban microcosm (the university campus) where natural, exotic ornamental, lawn, and NbS landscape types co-exist and are readily accessible, forming a kind of natural experiment for comparing these landscape forms. The native ecosystems we focus on are sage scrub and chaparral, which are prevalent native landscape types in Southern California (Avolio et al., 2020), remnants of which are preserved on the four university campuses selected for this study (University of California, Los Angeles – UCLA, University of California Santa Barbara – UCSB, University of California San Diego – UCSD, and University of California Irvine – UCI). The specific questions we pose and answer are informed by the two main approaches for combating extinction of experience addressed above (ecosystem conservation and restoration ecology), and include 1) is native landscape conservation (e.g., protection of native ecosystems in ecological reserves) or sustainable land development (e.g., implementation of NbS or replacement of turf grass with native plants) supported by the ecosystem service values of campus communities and 2) how do participant characteristics (age, academic discipline, environmental worldviews, etc.) shape how various landscape forms are ultimately valued? The implications of our findings for future land development, native ecosystem exposure, and extinction of experience are presented and discussed.

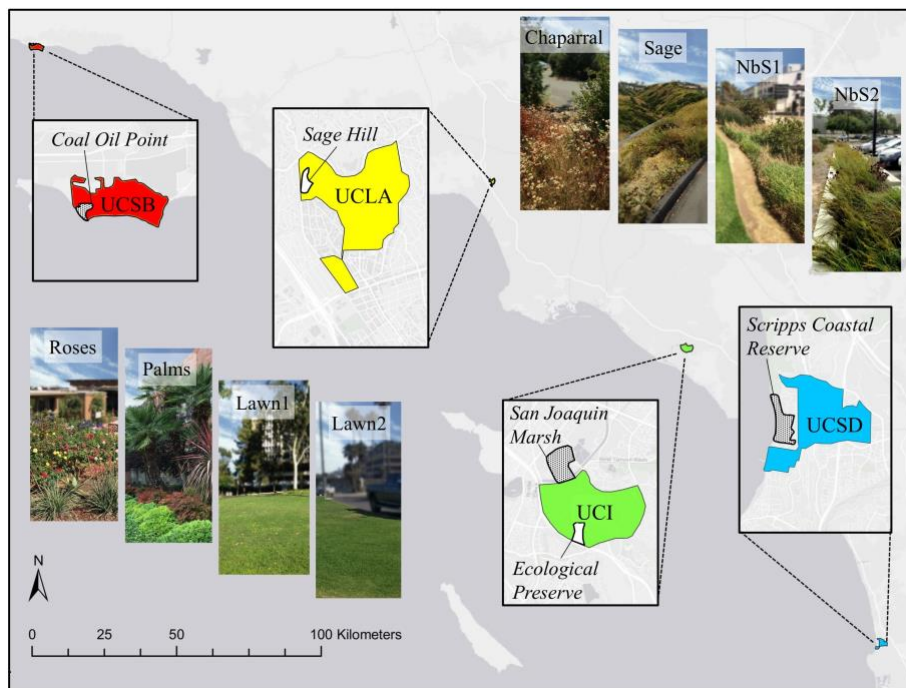
## 2. METHODS

### 2.1 Study Area

Student and staff perceptions of different landscape types (native ecosystem remnants, NbS,

gardens, and lawns) were surveyed at four University of California campuses (UCI, UCSD, UCSB, and UCLA; **Fig. 1**). These universities serve and employ between 25,000 and 45,000 students and 2,500-24,500 staff (**NCES IPEDS, 2018**). Approximately 44-66% of the land cover on each campus is impervious surface (buildings, parking lots, roads), with the remainder divided between irrigated landscapes (ornamental gardens, lawns) and native open space consisting of coastal sage scrub or chaparral. All campuses reside in urban areas, with UCLA being the most developed (i.e., located within the bounds of a megacity; **Adler et al., 2020**).

All campuses have sustainability initiatives that support design and implementation of



**Figure 1:** Map of surveyed university campuses. Nature reserves that are on or immediately adjacent to each campus are highlighted (stippled: UC Natural Reserve System; white: other nature reserves). Photographs illustrate different landscape types from across these campuses that were included in our perceptions survey. They include native landscape remnants (chaparral and coastal sage scrub), nature-based solutions (NbS1, NbS2), gardens (roses, palms), and lawns (lawn1, lawn2).

green stormwater infrastructure (**Pierce et al., 2021a**). This includes bioswales (also called rain gardens), permeable pavers, green roofs, constructed wetlands, and stream restoration. Student exposure to green infrastructure on campuses tends to be high because most green infrastructure

is located in student housing and new development. Campuses also support lawn replacement programs and tree planting initiatives that focus on revegetation with native species (**UCI WAP, 2017, UC Sustainable Practices, 2022**). This can take the form of native plantings in green stormwater infrastructure or more ornamental landscapes that support native pollinators and other native fauna.

In addition to the managed landscapes addressed above, the University of California system also supports native ecosystems as part of 1) the UC Natural Reserve System (NRS) and 2) local (i.e., campus-specific) conservation programs. Several of these reserves are adjacent to (or part of) campus grounds (see **Fig. 1**), making them an important resource to campus communities used for recreation, research, and education about native ecosystems (i.e., constituting classrooms without walls).

UCSD is immediately adjacent to the Scripps Coastal Reserve which provides access to nearly 1000 acres of native coastal sage scrub habitat via the Scripps Coastal Reserve Biodiversity trail. UCSB is located within three miles of the Coal Oil Point Reserve, which hosts a myriad of habitats, including coastal sage scrub, grasslands, dunes, and a seasonally flooded tidal lagoon (Devereux Slough). UCI is adjacent to the San Juaquin Marsh, a freshwater wetland fed by San Diego Creek and bordered by coastal sage scrub and grassland. The marsh is managed to maintain and enhance native biodiversity and is a hub for environmental learning and research on campus. UCI also hosts a 62-acre protected stretch of coastal sage scrub directly on-campus known as the UCI Ecological Preserve. This preserve is not part of the NRS, but is a critical ecological resource on campus. UCLA is the only campus that is not directly adjacent to an NRS site. It does, however, maintain the 3.4-acre Sage Hill Reserve, which features both coastal sage scrub and chaparral, and supports 7 native mammals, 17 species of butterflies and

30 resident or migratory bird species (**Loncore et al., 1997**). Indeed, the Sage Hill Reserve hosts the highest diversity of flora and fauna on UCLA campus, making it a valuable resource to the campus community (**Loncore et al., 1997**).

## 2.2 Survey Deployment

Our survey instrument was administered with Institutional Review Board approval (HS #2017-3998 and HS #18-1143) to graduate students, undergraduate students, and staff across the four University of California campuses described above. A fifth campus (UC Riverside; UCR) was also surveyed, but is not addressed here due to deployment restrictions that limited participant response rates. The survey was anonymous and distributed primarily through campus email listservs using SurveyMonkey (SurveyMonkey, Inc). A detailed description of survey deployment efforts on each campus can be found in Pierce et al. (**2021**) and Rippy et al., (**2022**). The total number of survey respondents was 1,088, approximately 0.7% of the population of students and staff across all four campuses (max coverage of 3.2% - undergraduates at UCSB, min coverage of 0.1% - graduate students at UCI; **Pierce et al., 2021**). This suggests that the surveyed population should not be viewed as representative of campus demographics as a whole. Rather, we treat it as a convenience sample that can be used to answer targeted questions about ecosystem services values and their association with different landscape types for a subset of university stakeholders.

To ensure the quality of survey responses, finished surveys were curated prior to analysis as in Rippy et al., (**2022**). Briefly, participants were excluded if their time to survey completion was more than 1 standard deviation below the median (i.e., they completed the survey in less than 25 minutes), they skipped more than five consecutive questions (indicating they were

rushing), they responded nonsensically to open ended questions, or they failed to answer question sets with built in consistency checks in a logical manner. The final participant pool following these quality control measures consisted of 734 university stakeholders, 28% of whom were graduate students, 54% of whom were undergraduate students, and 18% of whom were staff (**Table 1**). This breakdown is largely consistent with campus populations, which tend to be undergraduate dominated (**NCES IPEDS, 2018**).

**Table 1:** Participant characteristics

	a: Graduate Students	b: Undergraduate Students	c: Staff	d: All
P(G,UG,S) <sup>I</sup>	0.28 (0.21-0.34) <sup>b</sup>	0.54 (0.49-0.60) <sup>a,c</sup>	0.18 (0.11-0.25) <sup>b</sup>	--
1: P(UCLA)	0.26 (0.14-0.38) <sup>c</sup>	0.13 (0.03-0.22) <sup>c,3</sup>	0.61 (0.50-0.72) <sup>a,b,d,2,3,4</sup>	0.25 (0.19-0.32) <sup>c,3,4</sup>
2: P(UCSD)	0.24 (0.12-0.37)	0.32 (0.24-0.40) <sup>1,4</sup>	0.17 (0.01-0.33) <sup>1</sup>	0.27 (0.21-0.34) <sup>3,4</sup>
3: P(UCSB)	0.45 (0.34-0.56) <sup>c,4</sup>	0.48 (0.41-0.55) <sup>c,1,2,4</sup>	0.17 (0.01-0.33) <sup>a,b,d,1</sup>	0.41 (0.36-0.47) <sup>c,1,2,4</sup>
4: P(UCI)	0.04 (-0.10-0.18) <sup>3</sup>	0.08 (-0.02-0.18) <sup>2,3</sup>	0.04 (-0.13-0.21) <sup>1</sup>	0.06 (-0.01-0.14) <sup>1,2,3</sup>
1: P(Female)	0.62 (0.53-0.71) <sup>2,3</sup>	0.61 (0.54-0.67) <sup>2,3</sup>	0.68 (0.58-0.79) <sup>2,3</sup>	0.62 (0.58-0.67) <sup>2,3</sup>
2: P(Male)	0.32 (0.21-0.44) <sup>1,3</sup>	0.36 (0.28-0.44) <sup>1,3</sup>	0.26 (0.10-0.41) <sup>1</sup>	0.33 (0.27-0.39) <sup>1,3</sup>
3: P(Other)	0.05 (-0.03-0.12) <sup>1,2</sup>	0.03 (-0.07-0.13) <sup>1,2</sup>	0.07 (-0.11-0.24) <sup>1</sup>	0.05 (-0.03-0.12) <sup>1,2</sup>
P(Hispanic)	0.16 (0.03-0.29)	0.24 (0.15-0.33)	0.14 (-0.03-0.30)	0.20 (0.13-0.27)
1: P(Black)	0.01 (-0.14-0.15) <sup>2</sup>	0.02 (-0.09-0.12) <sup>2,3,5</sup>	0.01 (-0.17-0.19) <sup>2</sup>	0.01 (-0.06-0.09) <sup>2,3,5</sup>
2: P(White)	0.58 (0.48-0.67) <sup>1,3,4,5</sup>	0.38 (0.30-0.46) <sup>1,4</sup>	0.57 (0.45-0.69) <sup>1,3,4,5</sup>	0.47 (0.42-0.53) <sup>1,3,4,5</sup>
3: P(Asian/AA)	0.24 (0.11-0.36) <sup>2</sup>	0.34 (0.26-0.43) <sup>1,4</sup>	0.19 (0.03-0.35) <sup>2,4</sup>	0.29 (0.22-0.35) <sup>1,4</sup>
4: P(NA/PI) <sup>II</sup>	0.02 (-0.13-0.16) <sup>2</sup>	0.01 (-0.09-0.12) <sup>2,3,5</sup>	0 <sup>2,3,5</sup>	0.01 (-0.06-0.09) <sup>2,3,5</sup>
5: P(Other)	0.16 (0.03-0.29) <sup>2</sup>	0.24 (0.15-0.33) <sup>1,4</sup>	0.23 (0.08-0.39) <sup>2,4</sup>	0.22 (0.15-0.28) <sup>1,4</sup>
P(US.national)	0.80 (0.73-0.86)	0.88 (0.84-0.91)	0.90 (0.85-0.96)	0.86 (0.83-0.89)
P(California)	0.41 (0.30-0.52) <sup>b,c,d</sup>	0.80 (0.76-0.85) <sup>a,d</sup>	0.66 (0.56-0.77) <sup>a</sup>	0.67 (0.63-0.71) <sup>a,b</sup>
P(Pro.Env) <sup>III</sup>	0.58 (0.49-0.67)	0.53 (0.46-0.60)	0.56 (0.44-0.68)	0.55 (0.50-0.60)
P(Env.Mod) <sup>IV</sup>	0.39 (0.28-0.50)	0.57 (0.49-0.63)	0.47 (0.34-0.60)	0.50 (0.45-0.55)

a,b,c,d: comparisons between campus populations (grad, undergrad, staff, all)

1,2,3,4,5: comparisons within a demographic category (i.e., campus affiliation, race, gender)

I: G - Grad, UG - Undergrad, S - Staff; II: Native American or Pacific Islander; III: Pro Environmental; IV: Environmental Modernism

### 2.3 Survey Format

The survey instrument used in this study is the short-format survey described in Rippy et al., (2022), applied to a broader university demographic - undergraduate students, graduate students and staff (any discipline or profession), rather than engineering students only. The survey was

designed to identify the ecosystem services that university stakeholders most value and how they are associated with different landscape types (native ecosystem remnants, NbS, gardens, lawns). The survey also collected information about participant characteristics, including university status (undergraduate student, graduate student, staff), university affiliation (UCLA, UCSD, UCI, UCSB), academic discipline or profession, demographics (race, ethnicity, gender, nationality), and environmental worldviews, to place stated ecosystem services values and landscape perceptions in context.

2.3.1 Ecosystem services values: Participants were asked to quantify the importance (i.e., stated value) of seven ecosystem services (recreation, aesthetics, water quality, biodiversity, urban cooling, flood regulation, water conservation) and one disservice (allergies) by responding to the following prompt: “how much does each benefit or negative outcome of urban landscapes matter to you?”. Responses were recorded on a 7-point Likert scale (1 – not important to 7 – very important).

2.3.2 Landscape perceptions: To determine which ecosystem services or disservices different landscapes were perceived to provide, participants were asked to view eight color photographs of urban landscape features (one at a time, in random order) and rate the capacity of each landscape to provide the eight services and disservices noted above. Two photos were of native greenspace (sage scrub and chapparal), two were of NbS, two were of ornamental gardens (roses and palm trees), and two were of lawns (see **Fig. 1** for small-format images of each photo; survey participants were provided larger 9.9 cm by 19.8 cm images). All photos were selectively blurred as in Kendal et al. (2012) using graphics editing software (GIMP 2.8) to focus attention on the

landscape features of interest. They were also standardized to have the same sky color and brightness so that these elements would not influence how different landscapes were perceived.

Ecosystem service and disservice ratings were reported on a 7-point Likert scale (1 – this landscape will not provide this service or negative outcome to 7 – this landscape is very likely to provide this service or negative outcome). The following prompt was used: “I believe this system will [insert description of service or disservice]”. Services and disservices were described in plain language to make them clear to participants: flood regulation – *soak water into the ground, reducing flooding*; water quality regulation – *improve water quality*; water conservation – *conserve water, especially in summer*; urban cooling – *cool down the urban environment*; aesthetics – *make urban landscape more beautiful*; biodiversity – *increase diversity of animals*; recreation – *provide landscape for relaxation and recreation (walking, picnicking, biking, jogging, cycling or team sports)*; allergies – *cause allergies*.

2.3.3 Participant characteristics: Participants were asked to self-report gender, race and ethnicity, whether they are from the state of California, university status (undergraduate student, graduate student, staff), and university affiliation (UCI, UCSD, UCI, UCSB) using multiple choice questions that included options such as ‘Other’ and ‘Prefer not to state’. Country of origin, academic discipline, and job title/profession were solicited using open response questions.

Environmental worldviews (i.e., core beliefs that influence people’s attitudes about the environment and environmental challenges such as climate change) were assessed using the New Ecological Paradigm scale (NEP). NEP is a 15-question survey instrument intended to capture five key facets of environmental worldviews: (a) limits to population growth, (b) anti-anthropocentrism, (c) the fragility of nature’s balance, (d) rejection of human exemptionalism

(i.e., the idea that people are exempt from the constraints of nature), and (e) belief in ecological crises (**Dunlap et al., 2000**). We employ an abbreviated NEP instrument proposed by Saphores et al., (**2012**) to query environmental worldviews. The instrument includes two questions to characterize each environmental facet rather than the original three proposed by Dunlap (i.e., excluding questions shown to have low item-total correlations in other studies) (**Dunlap et al., 2000, Saphores et al., 2012**). Responses to NEP scale-questions were provided on a 5-point Likert scale (1: strongly disagree to 5: strongly agree). Principal component analysis (PCA) was performed on individual NEP responses to characterize dominant worldviews across environmental facets as described in Rippy et al., (**2021, 2022**) and Saphores et al., (**2012**).

## 2.4 Statistical Analyses

**2.4.1 Principal Component Analysis:** Principal component analysis (Matlab 2019b, Mathworks, MA) was used to identify dominant patterns (PC modes) in (a) ecosystem service values (importance ratings, section 2.3.1) and (b) perceptions about the relative provisioning of different services and disservices across native ecosystem remnants, NbS, gardens and lawns (service and disservice provisioning ratings for each landscape type, section 2.3.2). A resampling-based stopping rule was employed to identify PC modes that were significantly different than random (**Rippy et al., 2017, 2022**), representing meaningful patterns in how participants value services and how provisioning of them is perceived to differ by landscape type. Only significant modes (95% confidence level) were retained and interpreted in this study.

Given the large number of study participants individual participant scores are represented probabilistically in PC space using the empirical joint probability distribution of individual survey responses (**Rippy et al., 2021, 2022**). This creates probability heatmaps that are easier to

interpret than the point clouds that are often used to visualize PCA results. It also facilitates creation of difference surfaces that can be used to compare scores across individuals or landscapes. We employ this approach in this paper to highlight differences in how native landscapes are perceived relative to other landscape forms.

2.4.2 Factor Projection: Following PCA, environmental factor projection (Matlab 2019b, Mathworks, MA) was used to identify participant characteristics that significantly influenced either ecosystem service values or perceived services provisioning by landscape type. Briefly, individual participant characteristics (demographic variables, university status, university affiliation, academic discipline/profession and environmental worldviews) were projected onto the orthogonal plane defined by the first two principal components for (a) ecosystem services values and (b) landscape perceptions (**Davis, 2002**). The significance of each projected relationship was determined using bootstrapped Pearson's correlations, where the variables being correlated were 1) raw participant characteristics (prior to being transformed into PC space) and 2) predicted participant characteristics (the dot product of the first two PC scores and the projection matrix used to transform participant characteristics into PC space). Predicted characteristics will only approximate raw characteristics if there is a strong linear relationship between those raw characteristics and dominant patterns in the variable delineating the projection surface (i.e., ecosystem service values or landscape perceptions, respectively). Characteristics that were determined to be significant ( $p < 0.05$  level) and meaningful (Pearson's correlation  $> 0.2$ ) were used to identify groups of participants that might be expected to have different landscape preferences given their ecosystem service values and the services they perceive each landscape provides (described further below in section 2.4.3).

### 2.4.3. Electre III – Multicriteria Decision Analysis (MCDA): Electre III (package

OutrankingTools, R Core Team v. 3.6.3; **Bigaret et al., 2017**) was used to rank different landscape types based on their ability to provide valued ecosystem services. The goal of this analysis was to identify and compare the landscape choices that best meet ecosystem services needs for different groups of university stakeholders, paying particular attention to the ranking of native landscapes and NbS relative to gardens and lawns, as support for these landscape types has implications for native ecosystem preservation and sustainable land development on university campuses (**UCI WAP, 2017, UC Sustainable Practices, 2022**).

Electre III is an outranking model (**Roy et al., 1986, Roy, 1990**) that can be used to identify best landscape choices for particular individuals, or groups of individuals, on the basis of environmental decision criteria (in this case the ecosystem services people value). We elected to employ outranking approaches for multicriteria decision analysis instead of the commonly used Analytic Hierarchy Process (AHP) because outranking accommodates ordinal data (e.g., the Likert-scale ratings collected by our survey instrument), whereas AHP does not (**Kangas et al., 2001, Roy, 1990**). Use of outranking methods requires initial weights for decision criteria to establish their relative importance (**Rogers et al., 2000**). In our study these weights were determined by taking the geomedian of Likert-scale ratings for the value of each ecosystem service across all participants in a given participant group (groups identified as described in section 2.4.2) and normalizing the result so that the weights across all services summed to one (**Roy, 1990**). Outranking also requires a performance matrix that captures the perceived performance of each landscape alternative relative to each decision criteria (**Rogers et al., 2000**). In our study performance matrices were 8 by 8 square matrices (landscape type by ecosystem

service) containing the median Likert-scale rating for the perceived provisioning of each ecosystem service for each landscape type across all participants in a given participant group.

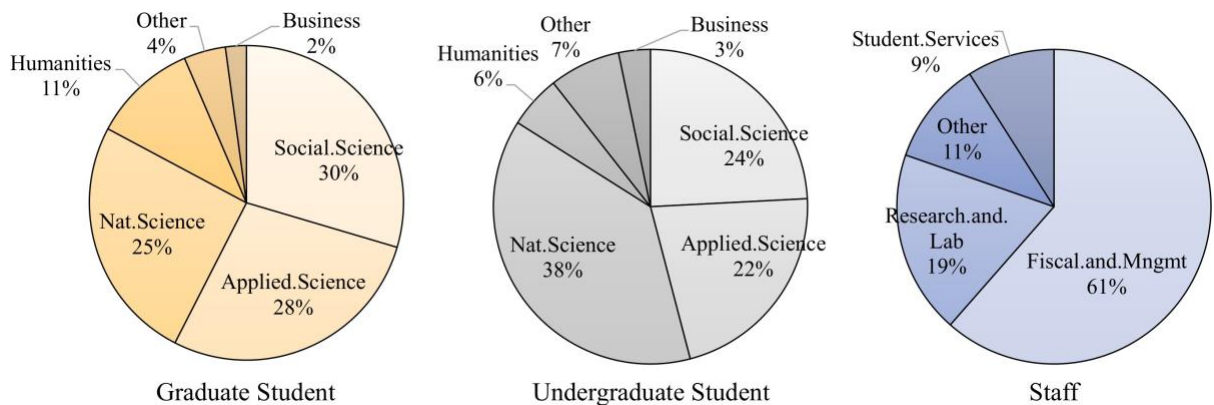
The simplest outranking approaches (Electre I, II) make use of only performance matrices and criteria weights to compare alternative options on a criterion-by-criterion basis, establishing their degree of relative dominance (outranking), across all criteria (**Rogers and Bruen, 1998, Rogers et al., 2000**). Electre III, however, accounts for uncertainties in how people perform valuation assessments by considering additional perceptual thresholds when determining dominance: (a) the indifference threshold, which indicates the level below which a decision maker is indifferent to differences between landscape types for a given decision criterion, (b) the preference threshold, which indicates the level above which a decision maker shows a clear preference for one landscape type over another for a given decision criterion, and (c) the veto threshold, which indicates the level where a discordant difference in a single decision criterion across any two landscape types is large enough that it will override any outranking relationships suggested by other decision criteria (i.e., the landscape performs so poorly relative to a particular ecosystem service that it could never be preferred) (**Rogers and Bruen, 1998, Rogers et al., 2000**). Because indifference, preference, and veto thresholds are not precisely known, landscape rankings were evaluated for a range of possible threshold values and the resultant medians (and associated error) were used to make final determinations of landscape preference. The following value ranges were used for each threshold, evaluated at increments of 0.5: Indifference threshold: difference of 0 to 1 Likert units, preference threshold: difference of 1.5 – 3.5 Likert units, veto threshold: difference of 3.5-5 Likert units.

### 3. RESULTS

### 3.1 Participant Characteristics

The characteristics of the university stakeholders who participated in this study are detailed in **Table 1**. Most participants were undergraduate students (54%), primarily from UCSB (48%) and UCSD (32%). Significantly fewer participants were graduate students (28%) or staff (18%). Approximately half of participating graduate students were from UCSB (45%) and more than half of participating staff were from UCLA (61%).

Graduate and undergraduate students were primarily drawn from the social sciences (e.g., economics, political science, psychology, sociology; 30%: grad, 24% undergrad), applied sciences (e.g., engineering, business, marketing, medicine; 28%: grad, 22%: undergrad), and natural sciences (e.g., biology, ecology, chemistry, earth science, physics; 25% grad, 38%: undergrad) (**Fig. 2**). Participating staff were most likely to have jobs in Administration, Management, or Finance (61%), followed by Research and Laboratory Services (19%), Other (e.g., library, communications, etc.; 11%), and Student Services (9%) (**Fig. 2**).



**Figure 2:** Academic discipline and profession of each type of university stakeholder (graduate student, undergraduate student, staff)

Participants were significantly more likely to be female than male across all university campuses (62% vs 33%; **Table 1**). Most self-identified as White (38-58%), followed by Asian/Asian American (19-34%), Other (inclusive of mixed race; 16-23%), and Black (0-2%) or

Native American/Pacific Islander (0-2%). Fourteen to 24% of participants self-identified as Hispanic. The majority were born in the US (80-90%), and most (41-80%; highest for undergrads) indicated they were from the state of California, which is logical given that UC campuses are California state schools.

Two significant environmental worldviews (pro-environmentalism and ecological modernism) were identified from participant responses to NEP scale questions. Pro-environmental worldviews were associated with strong agreement with anti-anthropogenic perspectives (e.g., feeling that people are not meant to rule over nature or that plants and animals have as much right to exist as humans), the perspective that nature is delicate and requires our protection and the perspective that future ecological crises are likely. Fifty three percent of undergraduate students, 56% of staff, and 58% of graduate students expressed pro-environmental worldviews (**Table 1**).

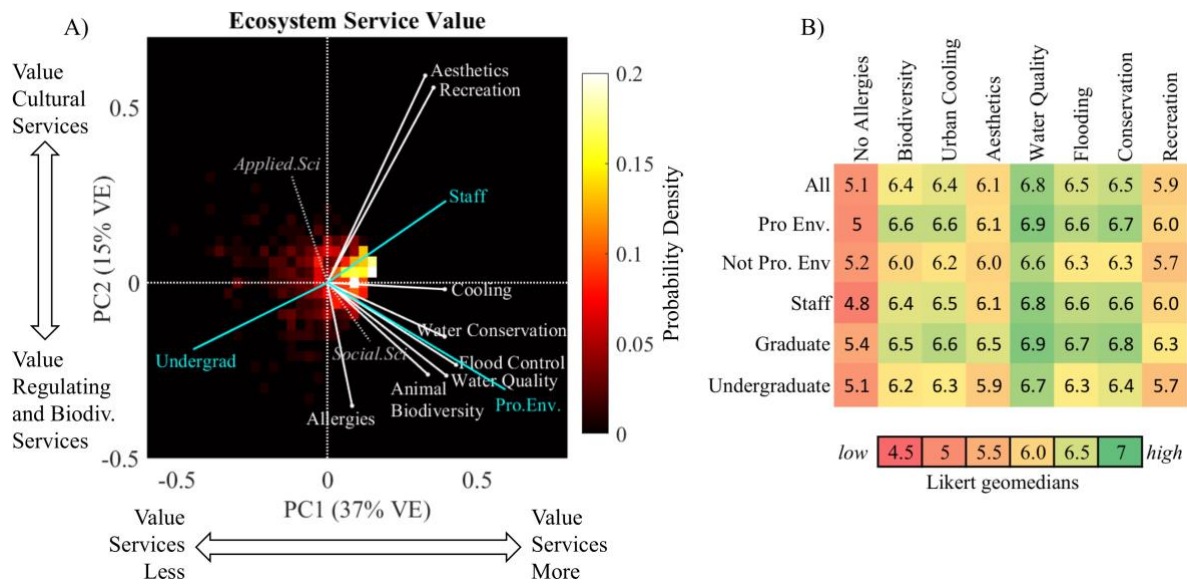
Ecological modernist worldviews were also widely held (i.e., by 39% of graduate students, 47% of staff, and 57% of undergraduate students; **Table 1**). Ecological modernists view human innovation as the solution to world problems (**Nordhaus et al., 2015**). Here, ecological modernism was associated with feelings of human exceptionalism (the idea that people will eventually learn enough about nature to be able to control it) and the perspective that earth's available resources are finite (i.e., human innovation might be needed to find viable global solutions).

### 3.2 Ecosystem Service Values

Principal component analysis revealed two significant patterns in ecosystem service values ( $p < 0.05$  level) that collectively explained 42% of the observed variance across university

stakeholders (**Fig. 3a**). The dominant pattern (PC1: 37% variance explained) separated out individuals who felt ecosystem services were valuable (positive PC1) from those who did not (negative PC1). Disservices (allergies) did not contribute significantly to this pattern. A secondary pattern (PC2: 15% variance explained) separated out individuals who valued cultural services more (aesthetics, recreation; positive PC2) from those who valued biodiversity and regulatory services more (animal biodiversity, flood control, water quality, water conservation) and considered allergies an important ecosystem disservice (negative PC2). The only service that did not significantly contribute to PC2 was urban cooling. Water quality (avoiding allergies) was the most (least) valued service across all university stakeholders (**Fig. 3b**).

Two participant characteristics (degree of pro-environmentalism and university status - undergraduate student, staff; cyan lines, **Fig. 3a**) loaded significantly and meaningfully ( $p < 0.05$ ,



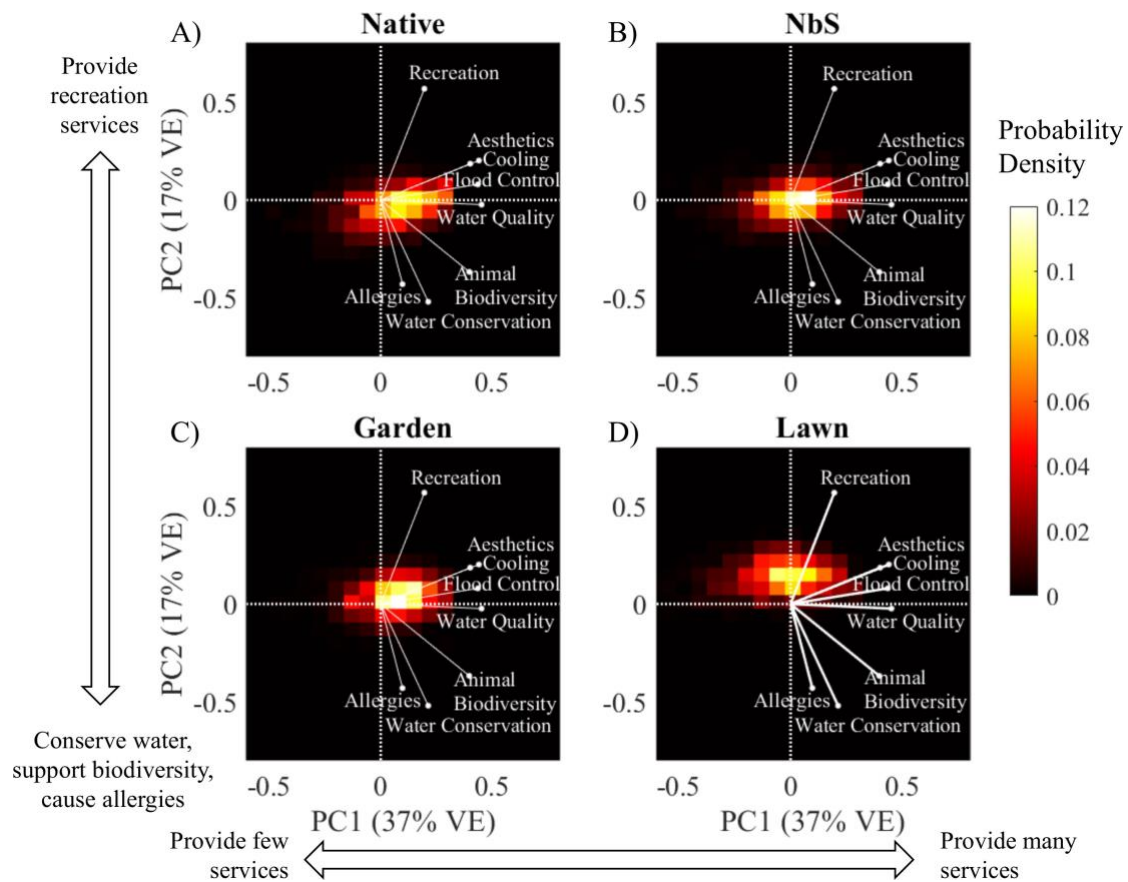
**Figure 3: A)** Principal component analysis of ecosystem service values (dominant pattern - PC1: x-axis, secondary pattern - PC2: y-axis). White vectors are ecosystem services; Vectors that strike primarily in the horizontal (vertical) contribute more to PC1 (PC2). The probability that participants felt particular services were valuable is shown using a heatmap (low probability = black to high probability = yellow/white). Participant characteristics that were significantly and meaningfully correlated with ecosystem service value ( $p < 0.01$ , Pearson's  $r > 0.2$ ) are in cyan. Characteristics that were significantly, but weakly correlated with value are in grey (dashed lines and text). **B)** Geometric median score for the value assigned to each ecosystem service by 1) all university stakeholders and 2) groups of stakeholders with significantly different ecosystem service values. Color: higher value services (green), lower value services (red).

Pearson's  $r > 0.2$ ) on the ordinal plane for ecosystem service values, pointing to consistent relationships between these characteristics and the value assigned to specific ecosystem services or groups of services. Individuals with pro-environmental worldviews tended to value ecosystem services more, particularly regulatory services and biodiversity, as evidenced by the strong concordance between the projected vector for pro-environmental worldviews and service vectors for water quality, conservation, flood regulation, and biodiversity (positive PC1, negative PC2; **Fig. 3a**). This pattern was strongest for biodiversity services, which were valued most differently across stakeholders who did or did not identify as pro-environmental (see **Fig. 3b**). Staff tended to value ecosystem services more than undergraduate students, particularly recreation (positive PC1, PC2 for staff; negative PC1, PC2 for undergrads; **Fig. 3a**). Staff were also the least concerned about allergies of any stakeholder group (**Fig. 3b**).

Discipline of study (applied science, social science; dashed grey lines, **Fig. 3a**) also loaded significantly, but weakly, on the ordinal plane for ecosystem service values ( $p < 0.05$ , Pearson's  $r < 0.2$ ). This suggests that the influence of discipline on the way services are valued is relatively minimal. Ecosystem services values were not significantly correlated with demographic characteristics (race, ethnicity, gender, nationality), university affiliation (UCLA, UCI, UCSD, UCSB), or job/profession.

### 3.3 Landscape Perceptions

Two significant patterns in landscape perceptions were detected ( $p < 0.05$  level). The dominant pattern (37% variance explained) mimicked the first principal component of ecosystem service values, distinguishing individuals who felt landscapes provide many services (positive PC1) from those who felt they provide few (negative PC1) (**Fig. 4**). Aesthetics, urban cooling, flood

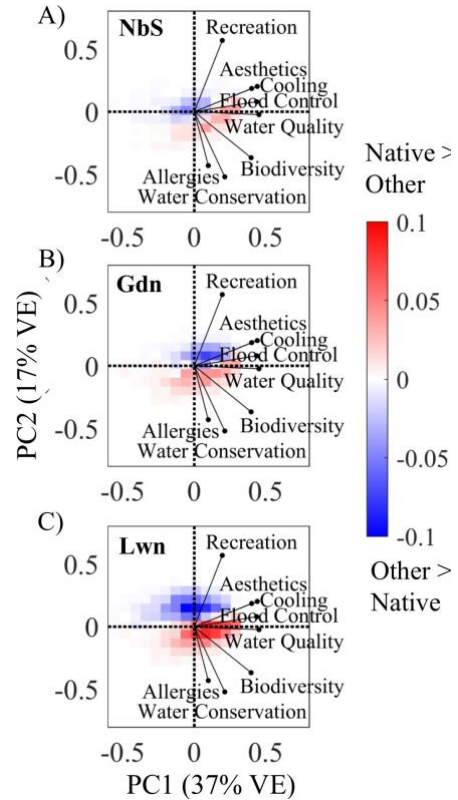


**Figure 4:** Principal component analysis illustrating perceived services and disservices provisioning by landscape type across university stakeholders: **A)** native, **B)** NbS, **C)** garden, **D)** lawn. The dominant pattern in landscape perceptions is on the  $x$ -axis (PC1). A secondary significant pattern is on the  $y$ -axis (PC2). White vectors denote specific ecosystem services or disservices. The probability that participants felt a particular landscape provides services or disservices is shown using a heatmap (low probability = black to high probability = yellow/white).

control, and water quality were the strongest contributors to PC1 (only the disservice allergies did not significantly contribute). The second pattern (17% variance explained) distinguishes different bundles of services and disservices people feel landscapes provide, separating out recreation services (positive PC2) from allergies, biodiversity, and water conservation (negative PC2). No participant characteristics loaded significantly and meaningfully ( $p < 0.01$ , Pearson's  $r > 0.2$ ) on the ordinal plane characterized by these patterns.

Different landscapes were perceived to provide different ecosystem services (i.e., the probability hotspot for each landscape was located in a different region of PC space; **Fig 4**).

Native landscapes were considered more likely to provide many services than few, particularly biodiversity services and water conservation, but were also more likely to be associated with the disservice allergies (positive PC1, negative PC2; **Fig. 4a**). Gardens were also perceived as more likely to provide many services than few, but were more associated with recreation and aesthetics than water conservation, biodiversity, and allergies (positive PC1, positive PC2; **Fig. 4c**). NbS and lawns were split about PC1, with NbS being perceived as slightly more likely to provide many services (i.e., the highest probability density for NbS is slightly to the right of the origin in **Fig. 4b** whereas the highest probability density for lawns is centered on the origin in **Fig. 4d**). Lawns, however, were clearly biased towards positive PC2 (recreation services), whereas NbS were not (i.e.,



**Figure 5:** Difference plots illustrating how perceptions of ecosystem services provisioning by native landscapes are different from perceptions of **A) NbS, B) gardens, and C) lawns**. Plots are oriented as in **Figure 4**. The red-blue color scale indicates instances where native (red) or other landscapes (blue) are perceived to provide certain services more.

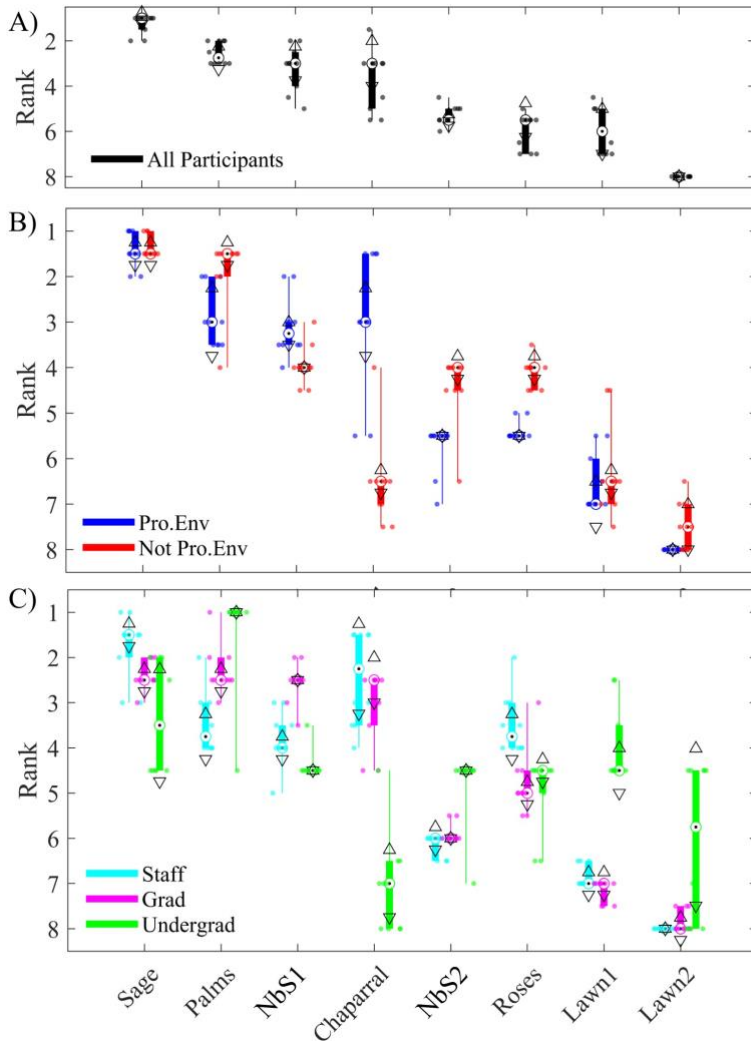
people appear as likely to associate NbS with recreation services as they are to associate them with allergies, water conservation and biodiversity services).

Although each landscape type had its own unique ecosystem service signature, difference plots comparing perceptions of native landscapes to other landscape types (paler color = less difference) illustrate that NbS were perceived most similarly to native landscapes (**Fig. 5a**), followed by gardens (**Fig. 5b**) and lawns (**Fig. 5c**).

### 3.4 MCDA – Electre III

Multicriteria decision analysis based on the ecosystem service values of all university stakeholders and the characteristic suites of services they associated with different landscapes suggest that one of the native landscapes evaluated, coastal sage scrub, is best able to meet the ecosystem service needs of campus communities (i.e., it was the most preferred landscape), followed by gardens containing palm trees, NbS1, and native chaparral (second best landscapes), NbS2, gardens containing roses, and Lawn 1 (third best landscapes), and Lawn 2 (least preferred landscape) (compare median values (targets) and associated 95% confidence bounds (triangles) for each landscape type in **Fig. 6a**). When university stakeholders are separated out into groups with different ecosystem service values (i.e., in accordance with the results of section 3.2), however, different patterns in relative landscape preference emerge. For instance, if we compare the landscape preferences of individuals who did and did not possess pro-environmental worldviews (blue and red colors, respectively, **Fig. 6b**), we see that pro-environmental individuals tended to follow the previously noted pattern in landscape preferences (an exception being lawns, which both received the lowest possible preference score), whereas individuals who were not pro-environmental had different preference patterns. This is most evident in the significantly elevated scores for gardens with palm trees, which become a top landscape choice, and gardens with roses, which move up to second-most preferred (alongside NbS), replacing native chaparral, which drops from second to last place (alongside lawns).

Landscape preferences also differed among staff, graduate students, and undergraduate students. Native ecosystems (sage scrub and chaparral) were most preferred by staff, followed by palms, roses and NbS1 (second best), and, in decreasing order, NbS2, Lawn 1, and Lawn 2 (cyan, **Fig. 6c**). Graduate students preferred native ecosystems, palms and NbS1 near equally,



**Figure 6:** Box and whisker plots illustrating the rank order of landscape preferences (sage scrub, chaparral, nature-based solutions; NbS, lawns, palm trees, and roses) given the ecosystem services participants value and their perceptions about the services each landscape provides. The photographs associated with each landscape code are provided in **Fig. 1**. Results are shown for **A)** the entire pool of university stakeholders, **B)** stakeholders with environmental worldviews that are more (blue) or less (red) pro-environmental, and **C)** different stakeholder types (staff – cyan, graduate student – magenta, undergraduate student – light green). Target symbols indicate the median rank of each landscape, triangles indicate the 95% confidence bounds about each median, the upper and lower bounds of each box are the 75<sup>th</sup> and 25<sup>th</sup> percentile bounds of our ranking estimates, and the whiskers span the full range of observed ranks (max to min).

followed by roses, NbS2, Lawn 1 and Lawn 2, in decreasing order (magenta, **Fig. 6c**).

Undergraduate students were the only group that significantly preferred an exotic landscape (palm trees) to native sage scrub, with palms becoming the most preferred landscape type (light green, **Fig. 6c**). All other landscapes received similar scores (note overlap of medians), excepting native chaparral, which ranked significantly below all other landscapes except Lawn 2.

#### 4.0 DISCUSSION

The overarching goal of this study was to evaluate how native ecosystems are perceived relative

different urban landscape forms (lawns, gardens, NbS), and gain insight regarding the degree to which measures that have been proposed to bring people closer to nature and combat “extinction of experience” (e.g., native ecosystem conservation and sustainable land development activities such as NbS installation or replacement of lawn with native plants) are supported by the ecosystem services values of campus communities. Our results indicate that native ecosystems, lawns, gardens, and NbS are all perceived to provide different groups of services such that no one landscape type can truly replace what is provided by the others (**Fig. 4**). This finding is consistent with **Rippy et al., 2022** (engineering student demographic), as well as other studies addressing landscape perceptions by the general public, many of which reveal strong, consistent associations with different landscape types, reflecting underlying cultural norms that govern how those landscapes are perceived (**Nassauer, 1993 and 1995, Ozguner & Kendle, 2006, Nassauer et al., 2009, Kurz & Baudains, 2012, Kendal et al., 2012, Peterson et al., 2012, Bertram & Rehdanz, 2015, Avolio et al., 2020**). Put another way, what is considered ‘normal’ in a social setting appears to influence how people feel a certain landscape *should* look, informing how it is ultimately perceived (**Nassauer, 1995**).

This kind of cultural norming may help explain why landscape perceptions weren’t significantly influenced by the personal characteristics evaluated in this study whereas ecosystem service values were (**Fig. 3**). Effectively, landscape perceptions appear to be part of our cultural identity (i.e., influenced by society), whereas the value we assign various ecosystem services reflects our personal identity (our inner self), which is a direct function of personal characteristics (**Schwartz et al., 2008, Hitlin, 2003, Kaymaz, 2013**). One consequence of this is that the variability we observe in landscape preferences across different stakeholder groups (pro-environmental vs not, or staff vs student) is largely a function differences in their ecosystem

service values, not how they perceive different landscapes.

Certain patterns in landscape preference were generally consistent across stakeholder groups, however, and may have important implications future land development and the relative utility of different approaches for connecting people to nature. In particular, we see evidence of 1) strong support for native ecosystems (particularly coastal sage scrub; evidence for chaparral is less consistent; **Fig. 6**), 2), support for turf replacement (lawns tended to receive lower preference rankings than most other landscape forms, suggesting there may be openness to reduced cover of this landscape type; **Fig. 6**), 3) support for iconic exotics (i.e., palm trees), particularly among youth (**Fig. 6c**), and 4) uncertainty about the value of NbS (i.e., they tend to be favored over lawns; **Fig. 6**, but are not viewed as a true substitute for native ecosystems; **Fig. 5**, falling somewhere in the middle of our landscape preference rankings). These four findings are unpacked in more detail below.

#### 4.1 Support for native ecosystem conservation

Native coastal sage scrub emerged as the most preferred landscape form across all groups of university stakeholders except university students, where it ranked as second most preferred (**Fig. 6**). This suggests that we can generally expect strong support for conservation of this native landscape form on Southern California university campuses, an important finding given the dramatic loss of coastal sage scrub in California over the past 75 years (totaling 85-95%; **Taylor, 2005**), which makes it one of the most threatened ecosystems in California (**Mooney and Zavaleta, 2016**).

Native chaparral was less consistently preferred, being ranked among the most or least preferred landscapes depending on the stakeholder demographic (**Fig. 6**). This may reflect

reduced exposure to chaparral on university campuses (all four support ecological preserves where sage scrub habitat is prevalent; chaparral is less common, present primarily around UCSB and the Sage Hill reserve at UCLA). However, it may also reflect characteristics of chaparral itself, which tends to be bushier and browner than sage scrub (see photos in **Fig. 1**). Aesthetic preferences for silver or green vegetation tones over browner ones are often reported in the literature (**Rippy et al., 2021, Kendal et al., 2012, Hoyle et al., 2017**), as are preferences for vegetation that looks less bushy, scruffy, or wild (**Li and Nassauer, 2020, Nassauer, 1995b**). Brown vegetation may also evoke reductions in other valued services if it is associated with plant dormancy or death.

Although support for native ecosystems was generally high, it is worth noting that the lowest support for both sage scrub and chaparral was observed among undergraduate students, our youngest demographic. This is consistent with recent concerns raised about declines in connection to wild nature among youth (**Pergams and Zaradic, 2008, Larson et al., 2019**) and the observation that nature disconnection tends to be most prevalent among young adults ages 16-24, which includes our undergraduate demographic (**Barrable and Booth, 2022, Hughes et al., 2019**). This may make opportunities for connecting to nature particularly important for this age group (**Hughes et al., 2019**), something that ecological preserves on campus are well suited to provide, both from a recreation and a research/education standpoint (**Hartig et al., 2001, Bowler et al., 1999**), so long as they are well advertised, accessible, and made good use of for campus activities and courses.

#### 4.2 Support for turf replacement

Lawns were among the least preferred landscape type across all groups of university

stakeholders evaluated here (**Fig. 6**), suggesting that campus communities may be open to reduced cover of this landscape type. This is consistent with present land development practices across all four campuses, where replacing decorative turf with native plants to conserve water resources is a priority (**UCI WAP, 2017, UC Sustainable Practices, 2022**).

The low rank of lawns may reflect their association with relatively few services (recreation and aesthetics, consistent with **Monteiro, 2017**), with a substantive fraction of individuals feeling lawns provide few services overall (recall the even split of the probability hotspot for lawns about PC1 – *many services vs few* – in **Fig. 4d**). This could make lawns unlikely to emerge as “a most preferred landscape” in a multi-service context where being multifunctional confers added benefit. This of course presumes that the value assigned to services other than aesthetics and recreation is relatively high. While this was certainly the case in our study (see **Fig. 3b**), other studies of private residential landscaping have shown that aesthetics can trump services like water conservation and biodiversity, dominating landscape preferences (**Hayden et al., 2015**).

Given the importance of values in shaping landscape preferences (and ultimately land development outcomes), understanding how and why values vary in different user contexts becomes essential (**Nassauer et al., 2001, Larson et al., 2009**). We expect that the degree to which a population possesses pro-environmental worldviews will be an important consideration in such assessments, as pro-environmentalism was more strongly correlated with ecosystem service values than any other participant characteristic in this study (consistent with **Larson et al., 2009 and Kaplan et al., 2012**). Other factors such as whether the lands in question are public (this study) or private (**Hayden et al., 2015**), may also play a role, with increased importance assigned to aesthetics in private residential spaces where landscapes are used to

signal care and worth to neighbors as well as provide services to residents (**Nassauer et al., 2009**). Support for turf replacement in these situations may be somewhat less evident than we observed on university campuses. However, Peterson et al., (**2012**) found that people often overstate the aesthetic value their neighbors assign to lawns, with many actually preferring a mixture of lawn and native plants, which still allows for turf conversion.

#### 4.3 Support for iconic exotics

Palm trees were ranked highly by most stakeholder groups and were the single most preferred landscape type for undergraduate students (**Fig. 6**). This suggests that although there may be support for turf replacement on university campuses that certain exotic garden species are there to stay. Widespread support for palm trees may be a reflection of their iconicness in Southern California; they were originally imported to evoke a tropical paradise, and (ironically) have taken the place of California natives as symbols of the region (**Pataki et al., 2013, McCumber, 2017, Avolio et al., 2020**). Support for palms is likely also a reflection of the value stakeholders assigned to the service urban cooling in Southern California's warm Mediterranean climate (**Manning, 2008**) (**Fig. 3b**). Palms were the only prominent tree in the foreground of evaluated landscape photographs (all other trees were blurred background elements), which may have made the palm garden more evocative of shade than other landscape types.

The other ornamental garden (roses) was generally less preferred than palms, despite being the only landscape with bright, colorful flowers. Flowers often have appreciable aesthetic value referred to as the "wow factor" (**Kendal et al., 2012, Hoyle et al., 2017, Rahnema et al., 2019, Rippy et al., 2021**), and attract butterflies, bees, and birds that provide valuable pollination services that were not explicitly factored into the landscape preference rankings evaluated here.

Given the present global decline in pollinators and pollination services (**Potts et al., 2010**), and the value of urban gardens in supporting pollinator communities (**Baldock et al., 2019**), this is something that should be revisited and would be expected to elevate the profile of floriferous gardens (exotic or native) in the landscape preference rankings detailed here.

#### 4.4 Uncertainty about NbS

Although there does appear to be support for conservation of native ecosystems and turf replacement programs on university campuses, it does not appear that NbS are viewed as similar enough to native ecosystems at present for NbS exposure to act as a stand-in for native ecosystem exposure, increasing overall awareness (see **Fig. 4a,b** and **Fig. 5**, which illustrate the differences between NbS and native ecosystems; Although these differences are lesser than those between native ecosystems and other landscapes, they are still marked). This finding is consistent with Rippey et al., (2022), where perceptions of NbS and native ecosystems were found to differ among engineering students, but is broader in scope (i.e., evident at the scale of entire campus communities, not just individual disciplines).

One possible explanation for the mismatch between how NbS and native ecosystems are perceived on university campuses concerns the stage of NbS implementation; NbS are a still a relatively new feature of urban California landscapes, which makes social norms for their perception less well developed (**Kim & Tran, 2018, Zuniga-Teran et al., 2020**). This is evident in the centrality of the probability hotspot in **Fig. 4b**, which suggests people still view NbS relatively neutrally (i.e., not strongly associated with any given service). This situation could change as NbS become more mainstream. We could wind up with more parallels being drawn between NbS and the native ecosystems they mimic or fewer, depending on the social norms that

develop and guide how they are perceived. Education about NbS and sustainable land development has an important role to play in this regard, as an ecologically informed aesthetic is something that is learned (**Gobster et al., 2007, Gobster and Westphal, 2004, Nassauer et al., 2001**); we must be taught to associate ecologically important functions and services with NbS so that the perceptual norms that eventually develop appropriately reflect them (**Rippy et al., 2022**).

Because there are presently few firm associations between specific ecosystem services and NbS, developing an ecological aesthetic for them on university campuses appears unlikely to require unlearning existing norms. This is important to recognize because unlearning is objectively more difficult than learning, requiring people to step outside their existing mental models (and associated habits) and try out something different (**Marques, 2007, Clark, 2008**).

## 5.0 IMPLICATIONS and CONCLUSIONS

Both approaches presently advocated for combatting extinction of experience (conservation and reconciliation ecology), appear to have strong support on Southern California campuses.

University stakeholders exhibited a high degree of support for native ecosystems, which bodes well for their ongoing conservation in ecological preserves; there was strong support for replacing turf with native plant communities (reconciliation ecology), as lawns were preferred significantly less than native ecosystems; and there was moderate support for implementation of NbS with native plants (also reconciliation ecology) (**Fig. 6**). This latter approach was the least well supported of the three, and would benefit from ongoing monitoring and evaluation as NbS become more mainstream (see discussion above). Overall, however, universities in Southern California appear to have myriad tools for increasing native ecosystem exposure and combatting extinction of experience that are well supported by campus communities.

Provided that future land development is consistent with community ecosystem service values, our study suggests that we can expect to see the following land development trends on Southern California campuses: 1) a trend towards native plantings and away from lawns (in line with state water conservation priorities; **Gleick et al., 2003, Grant et al., 2020, Spang et al., 2018, Browne et al., 2021**), 2) ongoing conservation of ecological preserves (Sage Hill at UCLA, the UCI ecological preserve, and the broader UC reserve system), 3) a gradual increase in NbS that is ultimately dependent on the norms that develop for how they are perceived (**Nassauer et al., 2009, Rippy et al., 2022**), and 4) preservation of iconic exotics in ornamental gardens such as palms, with the fate of traditional “English garden” elements such as roses being somewhat less clear. A central tenant of these predictions is that land development will closely adhere to ecosystem service values. In practice, however, social and economic services can be expected to intercede. Sage Hill at UCLA, for example, has been threatened by development numerous times in recent history, despite strong on-campus support for this preserve, because land is at a premium in space-constrained downtown Los Angeles (**Moradi, 2012**). Similar trade-offs between social, economic, and ecosystem services influence land development trajectories around the world (**Lant et al., 2008, Vidal-Legaz et al., 2013, Juutinen et al., 2019**), serving as a stark reminder that the values we ascribe to ecosystem services are not the only values that matter.

A final point worth considering here is the potential limitations associated with the use of *perceived* ecosystem services in studies like this one that address future land development. This issue warrants discussion because perceptions don’t always match reality. A clear example of a perception-reality mismatch that could have unfortunate land development consequences is raised in Rippy et al., (**2022**) where people were found to associate lawns (often fertilized) with

water quality services like nutrient removal more often than NbS, which are specifically engineered to provide such services. Mismatches like these illustrate that, while perceptions provide important insight into how land development might occur (the approach taken here), perceptions should not be used to make actual development decisions as they can favor landscapes that don't meet community needs. Real ecosystem service profiles are needed to drive actual development decisions. This makes characterizing the services different landscapes actually provide extremely important, particularly for novel designed ecosystems like NbS, where the degree of multifunctionality and tradeoffs across services are not yet well understood (Keeler et al., 2019, Tran et al., 2020, Kvamsas, 2022, Rippey et al., 2022).

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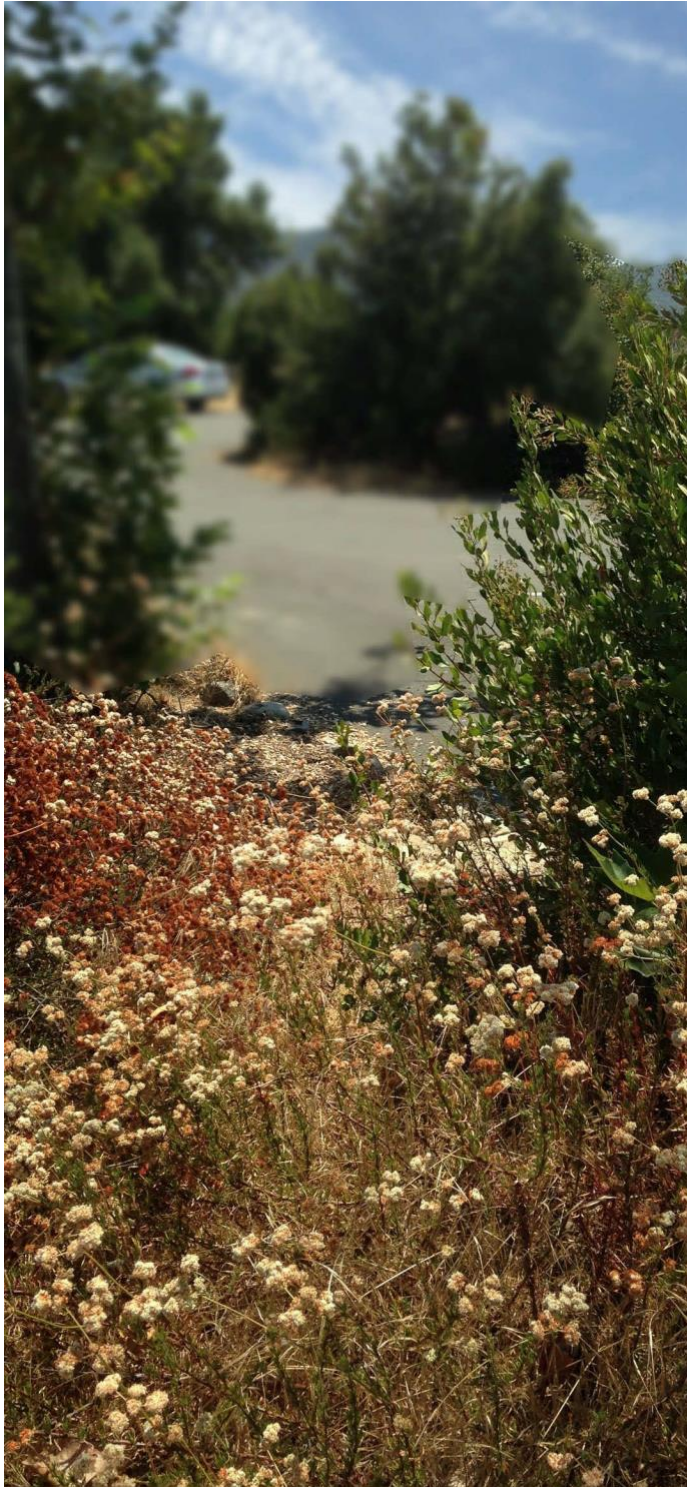
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APPENDIX A:

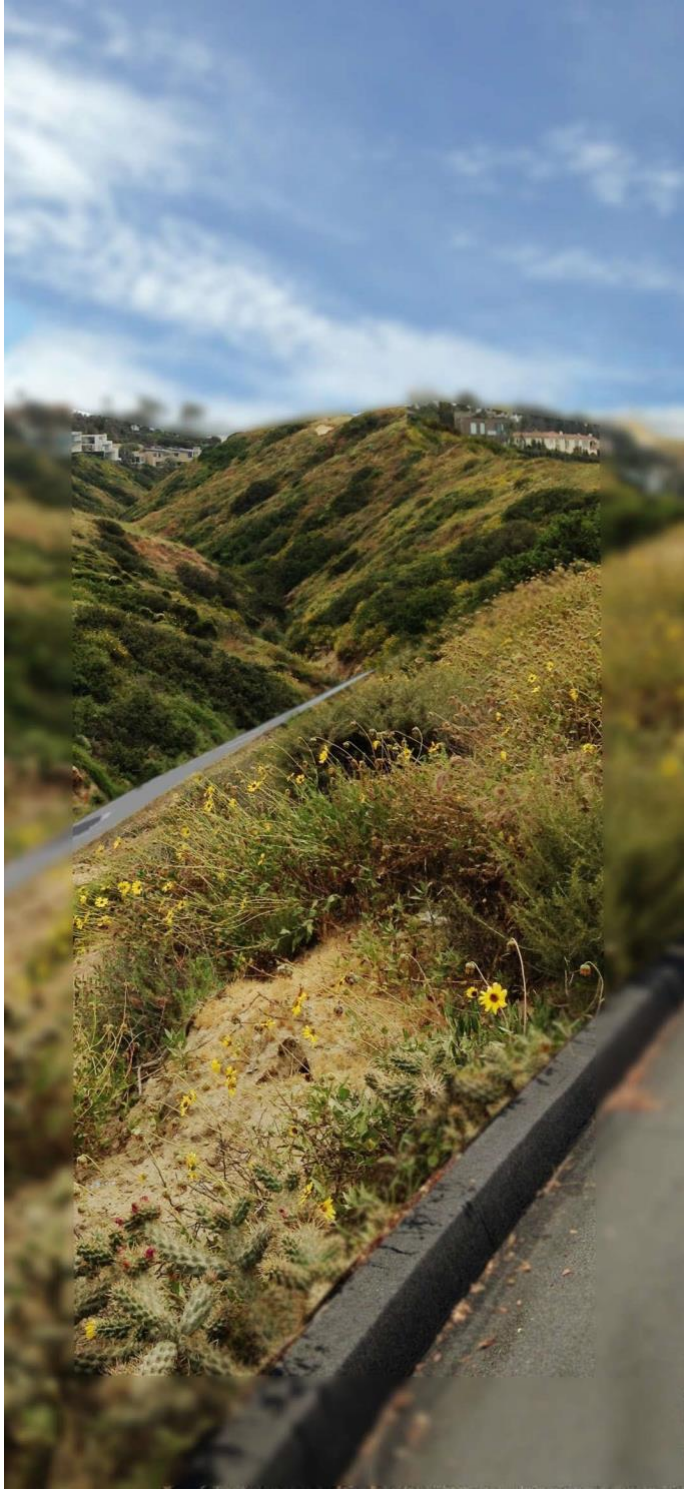
A.1: Survey Question – Ecosystem Service Values

How much does each benefit of negative outcome of urban landscape matter to you? (please address each outcome)	Not at all <span style="float: right;">Very Important</span>						
	1	2	3	4	5	6	7
Causes allergies							
Increases diversity of animals							
Cools down the urban environment							
Makes urban landscape more beautiful							
Improves water quality							
Soaks water into the ground, reducing flooding							
Requires a lot of water (especially in summer)							
Provides landscape for relaxation or recreation (walking, picnicking, biking, jogging, cycling or team sports)							

A.2 Photo Survey Photo's - Large Format Images



Native Chaparral



Native coastal sage scrub



Nature Based Solution 1



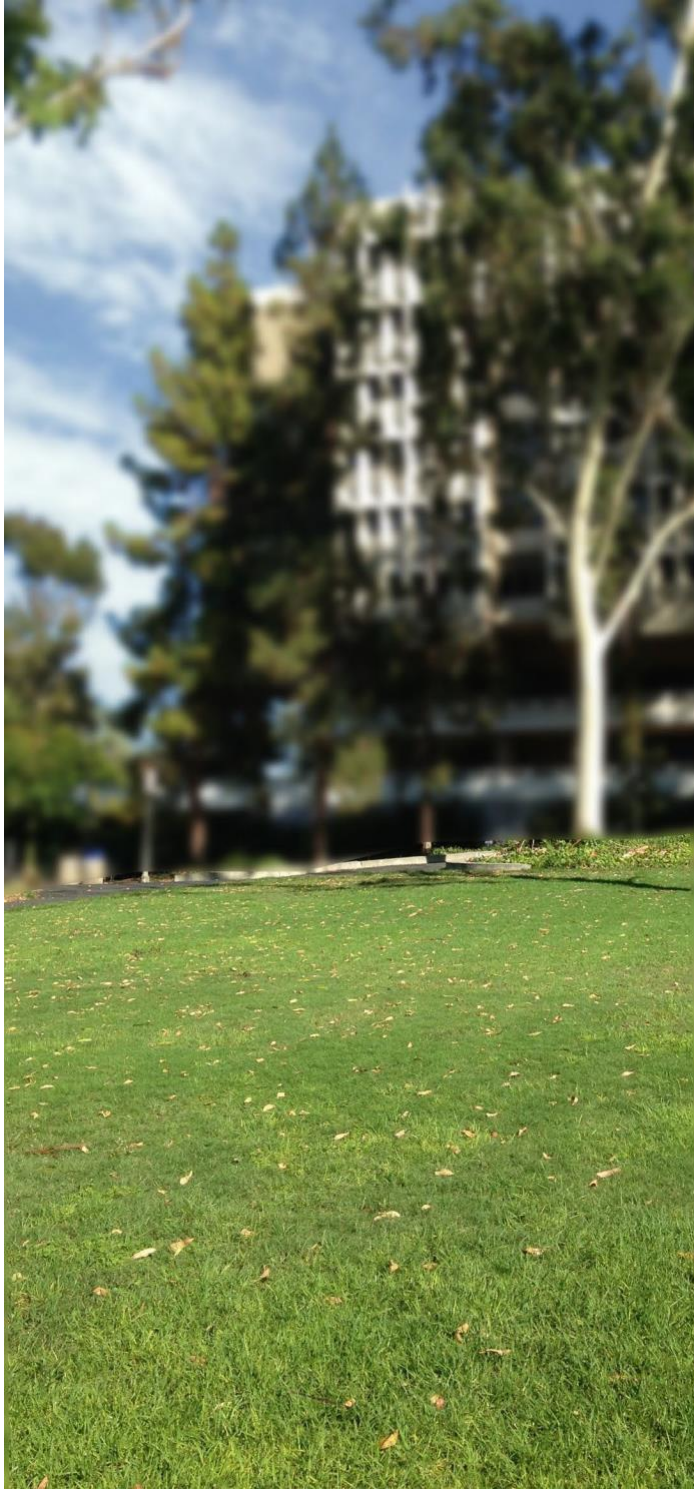
Nature Based Solution 2



Ornamental Palm Garden



Ornamental Rose Garden



Lawn 1



Lawn 2

A.3: Survey Question – Landscape Perceptions

Participants responded to the following prompt for each of the eight photographs shown above

<b>I believe that this system will</b> (please address each outcome)	Not at all <span style="float: right;">Very Likely</span>						
	1	2	3	4	5	6	7
Cause allergies							
Increase diversity of animals							
Cool down the urban environment							
Make urban landscape more beautiful							
Improve water quality							
Soak water into the ground, reducing flooding							
Require a lot of water (especially in summer)							
Provide landscape for relaxation or recreation (walking, picnicking, biking, jogging, cycling or team sports)							

#### A.4: NEP Scale Questions

<b>NEP-Scale Environmental Facets (1-7 Likert scale; 4 is neutral)</b>	<b>Pro-environmental worldview</b>	<b>Environmental modernist worldview</b>
<b>Balance of Nature</b>		
The balance of nature is strong enough to cope with the impacts of modern industrial nations	< 4 is pro-environmental	ns <sup>1</sup>
The balance of nature is delicate and easily upset	> 4 is pro-environmental	ns
<b>Limits to Growth</b>		
We are approaching the limit of the number of people the earth can support	ns	> 4 is env. modernist
The earth is like a spaceship with very limited room and resources	ns	> 4 is env. modernist
<b>Anti-Anthropocentrism</b>		
Plants and animals have as much right as humans to exist	> 4 is pro-environmental	ns
Humans were meant to rule over the rest of nature	< 4 is pro-environmental	ns
<b>Human Exemptionalism</b>		
Human ingenuity will ensure that we do not make the earth unlivable	ns	ns
Humans will eventually learn enough about how nature works to be able to control it	ns	> 4 is env. modernist
<b>Ecocrises</b>		
The so-called "ecological crisis" facing humankind has been greatly exaggerated	< 4 is pro-environmental	ns
If things continue on their present course, we will soon experience a major ecological catastrophe	> 4 is pro-environmental	ns

1: ns indicates concepts that do not significantly contribute to a particular worldview