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The Central Arizona Conservation Alliance Programs: Use of Social Media and App-Supported Community Science for Landscape-Scale Habitat Restoration, Governance Support, and Community Resilience-Building

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Abstract: Land managers are currently faced with a nexus of challenges, both ecological and social, when trying to govern natural open spaces. While social media has led to many challenges for effective land management and governance, the technology has the potential to support key activities related to habitat restoration, awareness-raising for policy changes, and increased community resilience as the impacts of increased use and climate change become more apparent. Through the use of a case study examining the work of the Central Arizona Conservation Alliance's social media ambassadorship and its app-supported community science projects, we examine the potential and realized positive impact that technology such as social media and smartphone apps can create for land managers and surrounding communities.

Keywords: social media; land governance; community resilience; online technology; community science; biodiversity conservation

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1. Introduction

1.1. Social and Ecological Challenges Abound for Land Managers

Land managers are faced with a myriad of social and ecological challenges, which are often compounded by a lack of sufficient resources and complicated social and ecological objectives [1,2]. Among these challenges are climate change and the impact of invasive species on the land, rapid urban development, habitat loss, and increased recreational use, which can bring problematic behavior on trails, campgrounds, and backcountry areas [3].

There is a noted acceleration of global habitat loss, fragmentation, and degradation due to a variety of human activities [4]. Rapid urban development and the growth of tourism and its associated infrastructure has led to the increase of urban–wildland interfaces, which are challenging to manage and present increased wildfire risk [5,6]. As needs for resources have thus far increased in connection to land, changing patterns of consumerism and a growing human population have also increased pressures on natural resources. Human activities, even removed from growing urban areas, can cause detrimental changes to habitats. These include the introduction of invasive species, increasing areas of edge habitat, and the changing fire and weather regimes. All of these present land governance challenges and can result in the loss of biodiversity and key ecosystem services [7].

These human-caused ecological challenges are compounded and linked with climate change, and are impacted by generally high levels of uncertainty regarding best practices for adaptable and effective management [8]. Climate change is already known to cause ecological changes, from shifting the ranges of individual species to complete ecological transformations. These changes may be incremental over the span of many years, or caused by the increased intensity and number of disasters such as wildfires, floods,

and storms [9,10]. Climate change also impacts local communities, often in detrimental ways [11,12].

In conjunction with natural forces, land managers must also plan for and mitigate changes to habitats due to human usage, including activities considered consumptive (such as resource extraction) and nonconsumptive (such as outdoor recreation) [2,7]. Of particular interest to this study are those "nonconsumptive" activities that have increased in their intensity consistently over time, for example, hiking, camping, OHV, shooting, mountain biking, etc. This is taxing the natural infrastructure, impacting the health of the landscape, and testing the innovation of land managers who are operating with limited resources while trying to ensure the safety of users [13]. The growing intensity of use is further complicated by changes in user behavior, influenced by traditional marketing, social media, tourism trends, and global conditions (e.g., the COVID-19 pandemic) [14,15].

1.2. Demonstrated Negative Impacts of Social Media and Apps on Land Management and Related Conservation

As with many aspects of modern life, social media and the use of phone applications (henceforth, "apps") has shaped the opportunities and challenges that land managers face worldwide. Each may influence user behavior such that there is an increase in the intensity of use in previously low-impact areas, degradation of sensitive habitats and archeological sites, handling of wildlife and artifacts, and dangerous behaviors driven by online clout culture and trends [16].

Among social media platforms, Instagram (iOS version 217.0; Android version 216.1.0.21.137; Menlo Park, CA, USA) has received considerable attention in this regard, although all platforms have the potential to cause similar issues depending on their level of popularity at any one time [16,17]. Using Instagram as an example, social media can influence behavior at scale by introducing large groups of people to landscapes previously unknown to them. The patterns (both algorithmic and human) of popularity among posts and images of these landscapes may drive some users to behave in ways perceived by them to receive more attention on the platform [18].

The rapid increase in the popularity of places such as Horseshoe Bend, AZ, USA, which has become an Instagram staple, has required infrastructural hardening of the site in order to manage impacts of increased traffic [19]. Further, images with animals, showing the account owner deeply immersed in the environment or depicting risky behavior, can result in more popular posts. Some notorious results of this include the death of a dolphin calf who was removed from the ocean by beachgoers and held for photographs for a prolonged time [20] and the many images of recreational users approaching charismatic wildlife such as bison [21]. Desire for depicted immersion also led to the degradation of the California poppy super bloom in 2019 [22]. There is a growing rise in recreational users who have damaged resources, and/or suffered injury and even death while posing for photos in the hope of attracting interest on Instagram and other platforms [23,24].

Among apps not otherwise considered as social media platforms, AllTrails (iOS version 14.3.0; Android version 14.2.0; San Francisco, CA, USA) serves as an example of the impacts these tools can have for land management. AllTrails is a popular crowd-sourced trail guide and tracker with information on hiking, biking, and OHV trails all over the world. While this is a powerful tool for users looking to explore and navigate via their phones, guides and maps are created by users, which means that they may represent non-established trails and can lack important safety, permitting, and access information. Users may be accessing sensitive areas and/or circumventing planned trail networks, and/or continue to use areas designated for rehabilitation or trail closure, due to these guides. Land managers may also find an increase in the need for rescues due to misrepresentation of trail conditions [25]. These guides can be edited and removed by land managers, but AllTrails only represents one of many such apps and the scale of the user-base-produced guides far outstrips that of land management staff [26].

1.3. Potential for Support of Land Management and Associated Community Well-Being by Social Media and Other Apps

Although the challenges presented by social media and other apps require the attention of land managers, there are also positive potential applications of these online tools including support for conservation activities via data collection, awareness raising for policy changes and increased community support, and enhanced community resilience to natural disasters related to climate change and biodiversity loss.

Land management and conservation have considerable and immediate data demands for informed decision-making. However, there is a lack of time or resources to collect sufficient information, and often actions must move forward with the available data [27,28]. Community science is one method to supplement and address data needs, as apps can serve as a means for collecting, collating, and even analyzing data [29]. Some common examples of apps that can support data gathering and community science include iNaturalist (iOS Version 3.2.4; Android Version 1.25.12; San Francisco, CA, USA), ESRI's (Redlands, CA, USA) Field Maps (iOS Version 21.4.0; Android version 21.4.0), and EDDMapS (iOS Version 1.0.9; Android version 1.1.8; Tifton, GA, USA), among others. Some of these will be explored in the case studies below.

Social media platforms can be used to elevate land manager messaging and create a sense of community between the public and land managers. This facilitated communication and increased transparency has been found to ease tension around changing policy and increasing cooperation [30]. The sense of community and avenues for free discussion via social media can also support inclusion, outreach and education, can increase support for ongoing land management activities, and increase public engagement surrounding planning processes [31,32].

Finally, research on community resilience would suggest that when properly applied, social media and other online technologies may be effective tools for supporting communities through natural disasters, such as those linked to climate change and biodiversity loss [33,34]. Community resilience may be defined as (1) a system's ability to return to a particular state after perturbations (such as natural disasters) and/or (2) an individual's ability to recover from disturbances (such as natural disasters) [35]. Social capital, or the sense of community and goodwill among members of a group, is understood to be closely linked with community resilience such that best practice would dictate the consideration of both infrastructural and social mitigation of disaster impacts [36]. Of the nine elements commonly associated with community resilience across the literature, social media and other online apps are likely to support five, including: local knowledge, community networks and relationships, communication, preparedness, and mental outlook [37].

It will be key for land managers to utilize digital tools to their benefit in this age of rapid change and social-media-driven trends. Ambassadorships and community science programs are two potential methods for harnessing the potential power of these digital tools to support land governance.

1.4. Introduction to the Central Arizona Conservation Alliance

The Central Arizona Conservation Alliance (CAZCA) is an initiative of Desert Botanical Garden (DBG), founded in 2012 out of Phoenix, Arizona, USA. The Alliance, as of 2021, consists of more than 60 partner organizations including parks and recreation departments at city and county levels, land managing federal and state agencies, and local nonprofits working on biodiversity conservation and community well-being, with DBG as the backbone organization [38]. The objective of CAZCA is to facilitate collaborative conservation efforts across the Central Arizona region, with a focus on Maricopa County and its associated HUC 10 watersheds, in order to create a network of natural open spaces. This network includes habitat blocks across the urban–rural gradient, as well as habitat corridors of varying sizes, and integrates already existing parks and preserves with habitats that are yet to be protected. These lands would serve as recreational areas for local residents and visitors, while maintaining thriving Sonoran Desert ecosystems.

CAZCA is designed to accomplish this by leveraging expertise and resources from organizations across the region and working towards the vision outlined above, as guided by the collaboratively developed Regional Open Space Strategy for Maricopa County (ROSS). The ROSS integrated leadership and feedback from more than 50 partner organizations to outline objectives for four primary goals includes: (1) protect and connect ecosystems across the region, (2) sustain and restore habitats protected in the present and future, (3) create spaces for local champions to love and support the network of open spaces, and (4) continue this work via the coordination and elevation of partner organizations and their work [39].

Functionally, as a fairly young collaborative conservation initiative as per the collective impact framework [38], CAZCA has and continues to accomplish many of its goals via collaborative programs and projects. Many of these focus on collective strategy development and decision-making, as well as on-the-ground conservation efforts such as invasive plant management and native plant material development. However, CAZCA has also innovated on land management issues through the use of social media (Sonoran Insiders) and community science using smartphone apps (Desert Defenders and Metro Phoenix EcoFlora, henceforth, EcoFlora).

It is our objective to utilize three case studies from among CAZCA's programs, where social media and smartphone apps have been successfully applied to land management challenges and community resilience building, to illustrate the realized potential of digital technologies and explore lessons learned and challenges faced.

2. Materials and Methods

We cover three different programs here to explore the role of social media and online technologies in supporting land governance in the arid southwestern USA (Table 1). All of these programs are collaborative in nature and focus on regions of varying sizes in Central Arizona. This general spatial focus is determined by the study area of CAZCA, which is defined by the location of our institution, Desert Botanical Garden in Phoenix, AZ, USA, and the Regional Open Space Strategy for Maricopa County.

Table 1. CAZCA programs explored in this case study in order of examination.

Program Name	Focal Area	General Objectives	Technology Utilized
Sonoran Insiders	Central Arizona, USA	Public education on land management, policy changes, and responsible use.	Instagram
Desert Defenders	Maricopa County, Arizona, USA	Map and monitor invasive plant species; share information on management strategies.	ESRI Field Maps, ESRI Collector, ArcGIS Online
Metro Phoenix EcoFlora	Phoenix Metropolitan Area, Arizona, USA	Collect, analyze, and share urban biodiversity data and information; increase the understanding and appreciation of plant life.	iNaturalist, SEINet, Instagram, Facebook, Twitter, Zoom

2.1. Sonoran Insiders' Programmatic Methodology

The Sonoran Insiders program seeks to create a community with local social media influencers to elevate messages about responsible use and raise awareness of the work performed by organizations to protect and maintain natural areas. The successes and lessons learned from this work illustrate the power and potential for social media to support land governance. It is a collaborative effort that includes leadership from CAZCA, the National Forest Foundation, and the Tonto National Forest as of 2019–2021.

The primary social media platform of focus for this program was Instagram. This platform was selected due to its historic impact on public lands and natural open spaces globally [14,17]. Furthermore, it remains one of the most popular social media platforms,

with roughly one billion users monthly in 2021 [40]. Instagram also strikes an impactful balance between visual and written storytelling in a way that facilitates strong messaging opportunities more suited to the needs of awareness-raising than Twitter (which previous to 2021, edited image display sizes automatically and limited the characters of a single post) or Facebook (which has severely cut its users' organic reach in recent years).

The Sonoran Insider social media ambassadors, or influencers that participate in the program, were initially identified based on their location, follower counts, and the quality of content in their Instagram feed. Local ambassadors self-selected, but no spatial boundary was drawn for the project. The collaborative agreement with the ambassadors included requirements for participation in in-person events, such that the participants themselves could determine if they were close enough to attend regularly.

In terms of follower numbers, we determined that influencers with 800+ followers would be ideal for our project needs and the resources available for the project. Our team's expert experience in the field indicated that this number would provide a robust minimum follower count and would avoid excluding most passionate ambassadors with smaller audiences. Furthermore, larger influencers often require payment for partnerships with them and we did not have such funds. We also prioritized the quality of influencer content in regards to responsible recreation practices and stewardship. We initially recruited local influencers who already demonstrated some interest in the outdoors or the environment through the use of local outdoor recreation hashtags such as #hikearizona and #explorearizona.

Ambassadors were then recruited through targeted digital outreach, either via direct messages on Instagram or via email. Upon joining, they signed a non-formal agreement to attend at least five events per year, create two to four posts on the events and another two to four posts about related themes such as Leave No Trace, wildfire prevention, invasive plant species management, etc. To assist the ambassadors with the sharing of key messages, we developed briefs that succinctly summarized the theme, messages, and calls to action. These include relevant hashtags, links, and sample text.

Some examples of responsible-use messages elevated by the program include: (1) methods for preventing human-caused wildfire and (2) exploration of the damage that off-trail recreation can have on microbiomes and non-charismatic species such as desert biocrusts. With the large increase in usage of public lands throughout 2020 due to COVID-19 impacts [41], ensuring these messages are reaching both new and long-term users is a key to lessening the impact of recreation on habitats and infrastructure. This is being accomplished at a scale that would not be within the budgets of many land managers [42].

2.2. Desert Defenders' Programmatic Methodology

There are a variety of invasive plant species (including buffelgrass (*Cenchrus ciliaris*), fountain grass (*Cenchrus setaceus)*, and stinknet (*Oncosiphon piluliferum)*) that are known to threaten both local community well-being and the habitats of the Sonoran Desert. Some outcompete native species for habitat and resources and impact the ecosystem services of Central Arizona, while many vastly increase wildfire fuel loads which has led to larger, more commonly occurring fires [43–45]. As these species are present across land jurisdictions and at a large and rapidly changing scale, effective management requires cooperation and sufficient data on where these species are, how their ranges change over time, and the success of treatment efforts.

Except in a few cases, land managers in this region lack the resources to accomplish all of this. CAZCA, with McDowell Sonoran Conservancy, Maricopa County Parks and Rec, White Tank Mountains Conservancy, Friends of the Tonto, the City of Phoenix Parks and Rec, the City of Tempe Parks and Rec, and Arizona Sustainability Alliance, set out to address this challenge via technology-supported community science in a project called Desert Defenders (DD).

The collaborative team has been utilizing ESRI's Collector and Field Maps smartphone apps to gather data annually on the presence of eight focal invasive plant species. With the

support of these apps, the professional team trains volunteer, community scientists how to identify the focal species and how to add data points on the regional map demarcating the location of the plants to best support local land managers each year. The process of adding data to the map is simple; community scientists download the ESRI Collector or Field Maps app onto their smartphone after they are trained to identify the focal invasive plant species. They then travel into the field, and use their smartphones and FieldMaps/Collector to mark GIS points in real time with data about the plant species found, what stage of life those plants are at, how many there are, and whether that area has been treated to manage invasive plants previously. Mapping activities can be initiated quickly and adapted to changing conditions, e.g., wildfires, early or particularly strong monsoons prompting invasive plant growth. The same apps are then utilized to track and monitor treatments by drawing polygons around those areas and can help determine best re-treatment approaches.

2.3. EcoFlora Programmatic Methodology

The EcoFlora project leverages community science to collect data on urban biodiversity, specifically plant life, and enhances community relationships with nature through technology, engagement, and communication. The project focuses on understanding the impacts of urbanization, accessible biodiversity data, and increasing the understanding and appreciation of plant life. By connecting with the community, contributing to local conservation efforts, and studying urban biodiversity, the project contributes to building community resilience.

EcoFlora is a collaborative project initiated by the New York Botanical Garden in 2016. In 2019, a National Leadership Grant from the Institute of Museum and Library Services was awarded to the New York Botanical Garden and partner gardens to expand the EcoFlora model across the United States. The partner garden recipients include the Chicago Botanic Garden, Denver Botanic Gardens, Desert Botanical Garden, and Marie Selby Botanical Gardens. Within the Desert Botanical Garden, the CAZCA team operates EcoFlora in the Phoenix metropolitan area (Figure 1).

The project collects data on urban biodiversity through iNaturalist (https://www.inaturalist.org/ (accessed on 11 January 2022)), a free web-based platform and app that is a joint initiative of the California Academy of Sciences and the National Geographic Society. Project members create observations with the mobile phone app, or upload images taken with a camera to the website. Photos can be coupled with suggested identifications, various annotations, and observation fields such as life stage, phenology, and associated organisms. iNaturalist neatly houses projects and observation data on their servers for free. This data is downloadable and open source, making it more accessible and useful for conservation efforts, land managers, and organizations. EcoFlora compares data from iNaturalist with the legacy data from the Southwestern Environmental Information Network (SEINet) (https://swbiodiversity.org/ (accessed on 11 January 2022)), a digital portal for floristic information that provides open access to floras, herbarium data, and collections. Species lists have been created with this comparison data and will provide preliminary information about plant biodiversity changes in the Phoenix metropolitan area over time.

EcoQuests are monthly challenges in addition to the overall project that ask members to observe specific species or ecological interactions. This is a venue for collecting specific data and information, and for collaboration. Working with community scientists, EcoFlora can provide supplemental data and support for other projects, organizations, and municipalities. One example is the project collaborated with the Great Milkweed Grow Out (GMGO) program at the Desert Botanical Garden to supplement data concerning western monarch butterfly decline. The EcoFlora model can also be implemented and utilized by other organizations; the Maricopa County Parks and Recreation Department modeled their EcoBlitz program after EcoFlora.

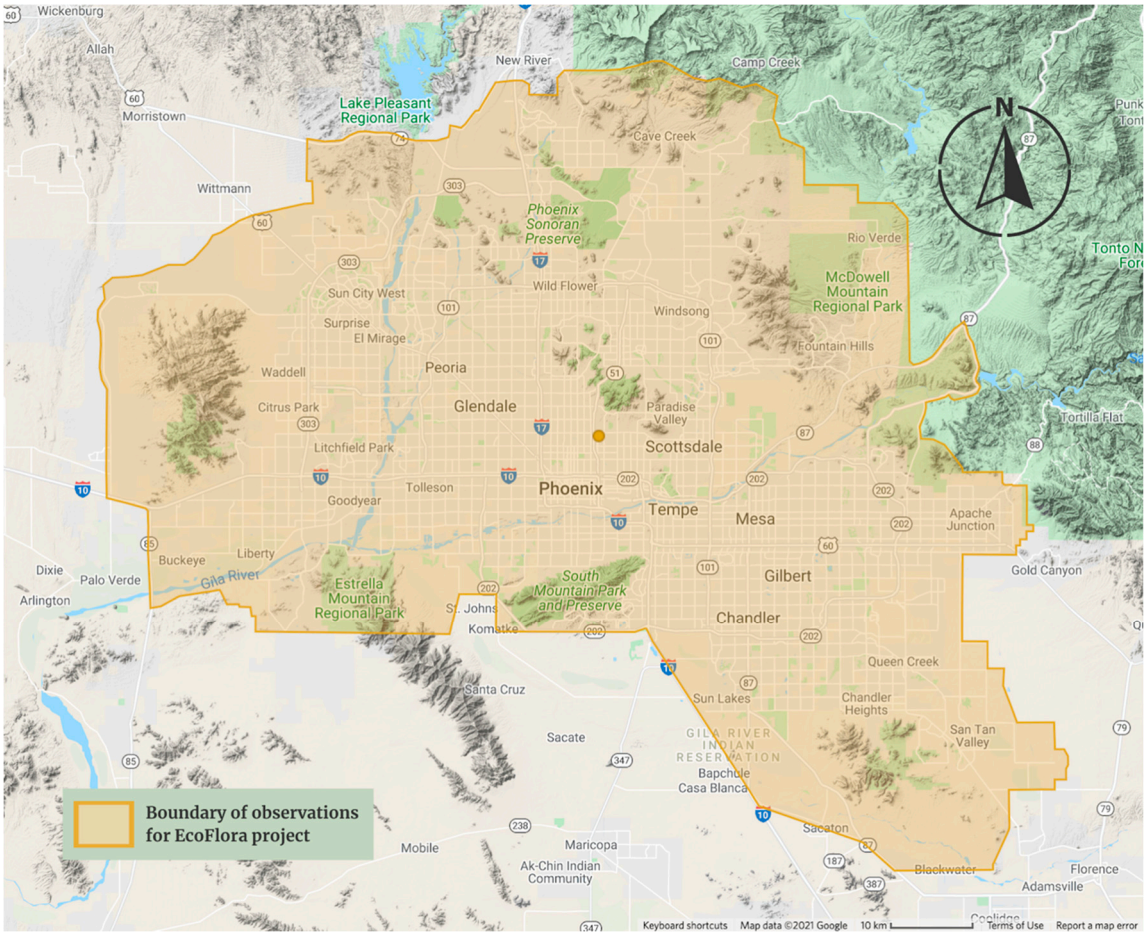

Figure 1. EcoFlora project boundary created with iNaturalist, using Google Maps data.

Engagement is the gateway to involvement and success in the project. Without an engaged group of community scientists, the project would not be able to gather sufficient data or increase community knowledge of biodiversity and plant life. The iNaturalist website includes a direct messaging feature, and this was extremely helpful in the early stages of the project to reach users already invested in using iNaturalist in the Phoenix metropolitan area. Further engagement has been garnered with video conferencing software and apps, such as Zoom (San Jose, CA, USA) and Google Hangouts, developed by Google (Mountain View, CA, USA), which allow the project to host virtual events and information and training sessions. This was essential when gathering in person was not feasible due to the COVID-19 pandemic. In-person engagement has included bird watching, moth lighting, and various botany-themed events. Through a monthly e-newsletter and social media and associated apps, the project has been able to maintain engagement and communication with members, inform them of project developments, and provide opportunities to increase their environmental literacy and plant appreciation. Social media specifically has provided the opportunity to communicate and engage with a wider audience.

3. Results

The quantitative social media and data-production results for each project will be represented in this section, along with qualitative outcomes for the congruity of our case study explorations.

3.1. Sonoran Insiders

Over the course of Y1, the number of Insider posts increased as the community of ambassadors grew and the program engaged more with the participants through events,

online discussions, and social media collaborations (e.g., Instagram take-over and Insider-led hiking webinar). This trend culminated in the largest number of posts in December 2020 (n = 52; Figure 2).

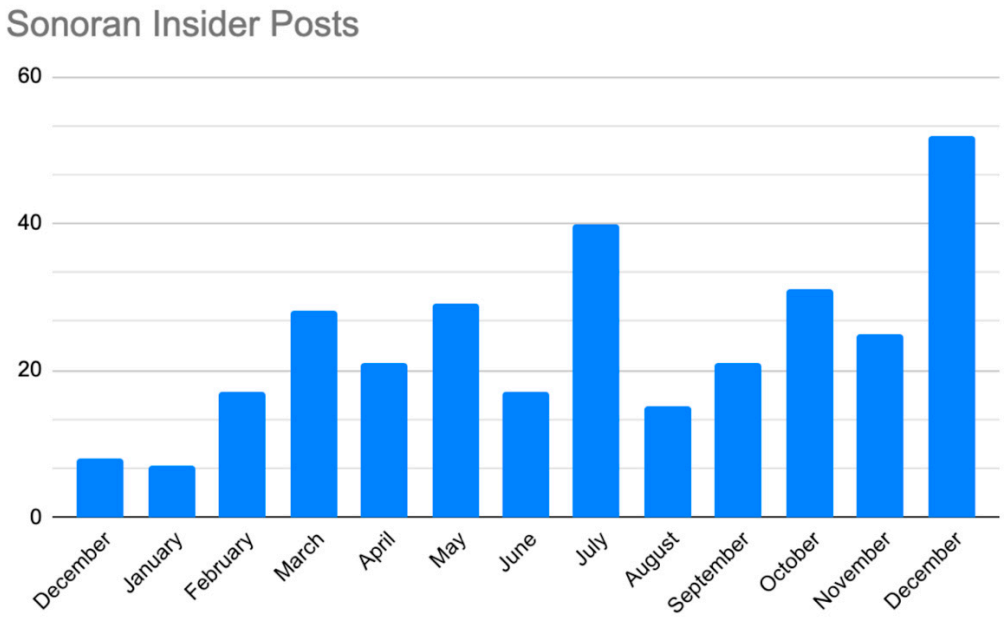

Figure 2. Number of posts on Instagram with the hashtag #sonoraninsiders by month, from December 2019–December 2020.

The impacts of ambassador posts were measured via their reach on Instagram. The term "reach" here refers to the number of unique users that saw the Instagram post using the #sonoraninsiders hashtag on any given day. This number was calculated by adding all of the followers of each account that engaged with the post using the hashtag. The Sonoran Insiders hashtag was used 311 times during year one, accumulating 57,059 likes. We had an annual reach of 5,996,329 people and an average monthly reach of 935,641 people. For reference, the estimated cost of reaching 6 million people with an online ad campaign could range from $18,000 to $60,000, with an average cost per thousand impressions of $3–$10 across the main advertisement platforms [46]. Due to the focused nature of our ambassador audiences, it is possible that the value of this outreach is underestimated, as the posts produced are organically targeting relevant audiences to land managers.

Support for conservation is produced in two ways through this program: (1) by elevating responsible-use behaviors to help protect sensitive environmental and cultural elements of the landscape and (2) raising awareness for volunteer opportunities and charitable support of conservation programs and events. Themes communicated through this social media outreach are shaped by the leading collaborators of the Sonoran Insiders program, in conjunction with other land-managing partners involved in the monthly events on which messaging is based. For example, in early 2020, the program partnered with the McDowell Sonoran Conservancy (MSC) for a behind-the-scenes tour of ecological and restoration research run in the McDowell Mountains Preserve. MSC then led the crafting of the brief, as well as the narrative and calls-to-action presented at the event itself.

3.2. Desert Defenders

The Desert Defenders community science mapping activities have been active from December 2018 to July 2021, with increasing participation from local land managers over time. This has produced a regional map (Figure 3) of the focal invasive species from lands managed by Maricopa County Parks and Recreation, and the City of Scottsdale, City of Tempe, and City of Phoenix parks and recreation departments. This map includes

6824 observations from more than 100 community scientists. Table 2 illustrates the number of data points for each of the focal invasive plant species.

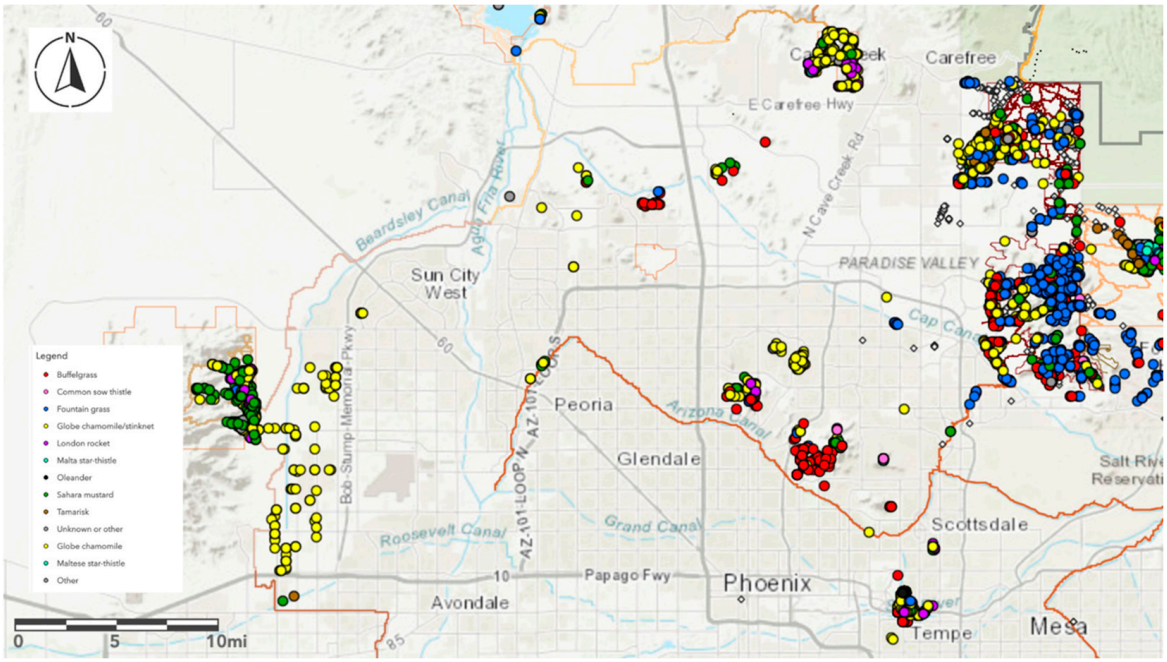

Figure 3. Example map for Desert Defenders; colored points represent different species of focal invasive plants identified across the region as of Spring 2021.

Table 2. Focal invasive plant species and number of data points for each produced by community scientists from 2018–2021.

Species Name (Common)	Number of Data Points
Buffelgrass	659
Common sow thistle	66
Fountain grass	1788
Globe chamomile	1704
London rocket	600
Maltese star-thistle	159
Oleander	38
Sahara mustard	1130
Tamarisk	137
Unknown or other	251

There are several key impacts from this project. First, the data gathered by community scientists through the apps has given land managers access to annual spatial data on invasive plant species across the landscape (Table 2). In 2021, thanks to these efforts, a regional map was created, with minimal monetary investment from land managers outside of the modest staff time and the ESRI licenses necessary for volunteers to use the app. This cost could be further limited through the use of free apps such as EDDMapS, launched and maintained by the University of Georgia. In any case, this data allows for annual planning for treatments that make the most efficient use of limited resources. It has also provided information for the movement of invasive plant species across the region, facilitating collaboration and management among land managers across jurisdictions.

3.3. EcoFlora

Key impacts from the project include open-access biodiversity data, alleviating plant invisibility and increasing support for conservation, and community resilience through involvement in community science. As mentioned above, iNaturalist and SEINet are both open-access platforms, making the data and collections gathered through EcoFlora available to anyone interested in viewing or using them. The project began in February 2020 and as of December 2021, 361 people have become project members and 37,319 observations (21,175 plants) of 2577 species (1158 plant species) have been made by 252 observers, with 1802 identifiers (https://www.inaturalist.org/projects/metro-phoenix-ecoflora, accessed on 14 December 2021) (Figure 4). iNaturalist observations have provided a wealth of open-source data, which would otherwise be extremely difficult to achieve without an abundance of community scientists.

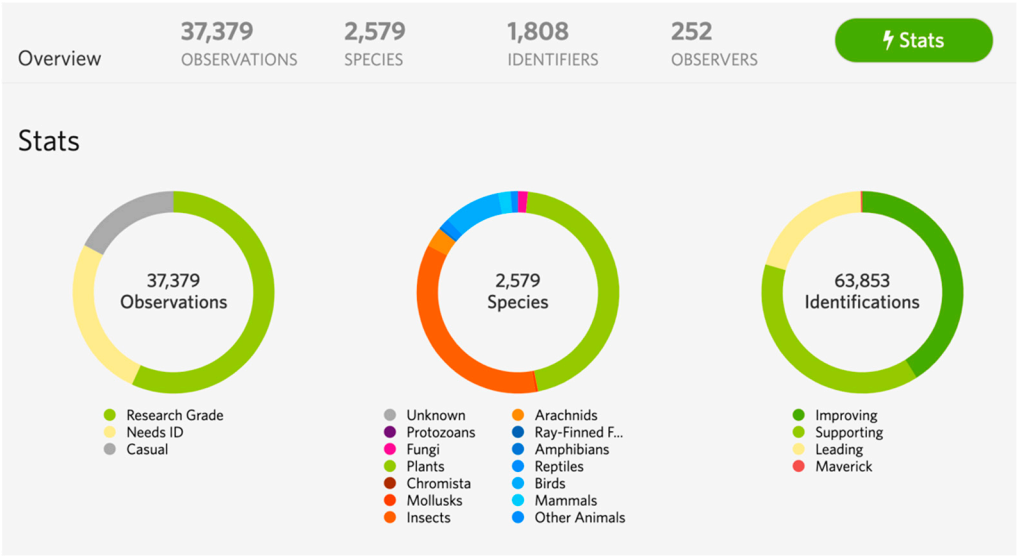

Figure 4. Screenshot from EcoFlora project page on iNaturalist website showing current project stats.

People and communities can directly participate in EcoFlora in a way that is not intimidating or technologically overwhelming. Project members can make observations in their own neighborhoods, in a place they have local knowledge of, and can connect their lived experience with. They understand their needs, wants, and challenges, and feel the ramifications of policy and daily changes better than those outside do. They are more likely to notice a new plant species or understand where street trees that provide shade would be most valuable. Through iNaturalist, project members can use the species information, observation images, and maps to support conservation and intersectional environmental efforts in their community. For the EcoQuest in October 2020, project members observed 624 ocotillo plants (*Fouquieria splendens*), bringing the total number of observations in the Phoenix metropolitan area to 1056. With this observation data, community members can see possible corridors for pollinators and wildlife that connect to open space (Figure 5). This can be used by the community to advocate for connectivity corridors, in turn contributing to landscape management efforts and community well-being through increased nearby nature in urban areas [47]. Project members can communicate and build relationships with one another through interaction on the iNaturalist platform and the project's social media accounts. These venues allow people to actively take part in community conversations about urban biodiversity.

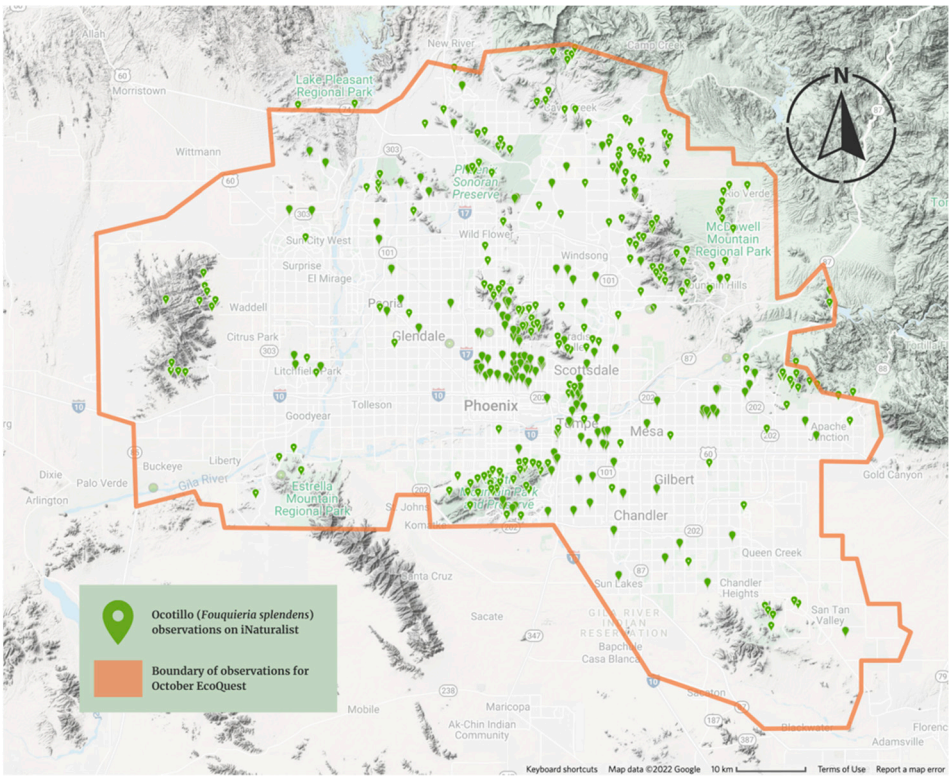

Figure 5. iNaturalist map showing observations of ocotillo (*Fouquieria splendens)* and possible connectivity corridors in the Phoenix metropolitan area, accessed on 5 January 2021.

Events hosted by EcoFlora give people the opportunity to connect with scientists, local leaders, organizations, and professionals. EcoQuestions, for example, are virtual question and answer sessions that provide the opportunity for project members and the community at large to learn more about urban biodiversity and plant science. In total, project events and training sessions have been attended approximately 270 times, with the project having 1081 followers collectively on Facebook, Instagram, and Twitter. Increased support for conservation ideally follows increased awareness and understanding of plant life and biodiversity. Collaborations, events, and social media presence equate to the public learning more about plants and biodiversity, alleviating plant invisibility (previously plant blindness), or the tendency for people to overlook plants and view them with lower regard than other life forms [48].

EcoFlora has a positive impact on the mental and physical health of the community through encouraging physical activity and providing mental stimulation. Project members have repeatedly stated that EcoFlora has provided them with an outlet, specifically throughout the COVID-19 pandemic. Making observations can be done alone or when socially distanced, and is an activity that can safely be done outdoors. EcoQuest challenges also give project members something new to look forward to every month, contributing to well-being through anticipation of future positive events [49].

4. Discussion

In regards to land governance, social media and other online applications are often posed as challenges. For example, clout-chasing may cause users to engage in behaviors that risk their safety or the natural resources themselves [23,24]. These tools can cause rapid increases in area use over a relatively short period of time, making management and infrastructure development a game of catch-up [19]. With limited resources, both in terms of monetary support and staff capacity, land governance may be faced with resulting changes that damage resources, degrade trust, and create new use-norms that undermine conservation efforts.

These are all serious concerns. However, much of the evidence for such impacts is rhetorical, with increasing calls for closer studies of these impacts, to understand when they manifest and how [32]. At the same time, there are large potential benefits for both users and land managers that include increased equity of access and much-needed social support for land governance activities. As we will demonstrate below, our models specifically demonstrate the positive benefits of social media and other online applications (such as iNaturalist and ESRI Field Maps) in regards to support for (1) biodiversity conservation, (2) land governance and policy changes, and (3) building community resilience.

4.1. Sonoran Insiders

The Sonoran Insiders program contributes to community resilience in a variety of ways in the face of disasters such as those caused by climate change and biodiversity loss. In particular, when considering the common elements of community resilience as identified by Patel et.al. in their 2017 systematic review [37] of the concept, four common elements are positively impacted by this application of social media to land governance. (1) Social media through the Insiders program has increased local knowledge around land management, related disasters, and modes for community involvement in protecting natural resources and local infrastructure from disasters. (2) The Insiders program builds community networks and relationships between land managers and the public. (3) It increases communication between and among land managers, program ambassadors, nonprofit partners, and the public. (4) Through all of this, messaging and connections formed through the project have the potential to increase hope among community members and, thus, improve mental outlooks.

There is considerable need for volunteer support for land management activities ranging from infrastructure maintenance to ecological research. Volunteers can be difficult to recruit, and the costs for finding a sufficient volunteer force can include marketing costs, as well as the time and capacity of volunteer coordinators (where available) [50]. Thus, alleviating those needs through effective social media messaging can represent another economic and social support for land managers.

Social media ambassadors and related social media communications have also provided support for land managers in cases of contested policy changes. For example, in 2021, the City of Phoenix city council voted to institute trail closures during extreme heat days. This decision was made following an increase in the number of rescues on the popular and difficult Echo Canyon and Piestewa Summit trails, with the associated health impacts on rescue personnel. While the rationale for these trail closures was logical and promoted safety among both trail users and city staff, there was considerable pushback from some sectors of the public to these closures [51]. A lack of cooperation with safety measures and other land management policies can undermine safety and create resource sinks. Thus, effective communication with trail-use communities is essential, in this case, among both local users and tourists. Social media platforms, particularly those run by local influencers, have the potential to reach both groups. Furthermore, communication from other users, as opposed to perceived authority figures, can enhance the acceptance of new rules and use patterns [52].

While this program has seen a variety of high-impact successes, even while at a pilot stage, there are challenges to be accounted for when considering the social media ambassadorship model. First, while monetary investments are low compared to equivalent marketing expenses, staff time may be considerable. Consistent engagement among ambassadors and between ambassadors and program staff is also essential for trust building. This also requires a significant time investment by staff. For CAZCA's program, this was mitigated through collaboration among several organizations, which allowed for sharing of the planning, organizational, and community-building duties.

4.2. Desert Defenders

In conjunction with the raw data provided, the DD program bolsters land managers in a variety of social ways. The training modules designed by the collaborative group include extensive knowledge on the role of invasive plants in ecosystem shifts and increases in wildfire risk for the community scientists. Thus, through involvement in the program, members of the public gain hands-on conservation experience and have become advocates and supporters for management efforts. In some cases, these community scientists have led the mapping projects themselves in support of small municipalities, reached out to their home owners associations (HOAs) about invasive plants in local landscapes, and raised money to purchase equipment for invasive plant management efforts [29].

The data produced by the project also supports community resilience, particularly in regards to pressing wildfire threats in the southwest. In particular, this data is essential for the effective management of these invasive plant species such that the community and the surrounding habitats can be protected from heightened wildfire risk and biodiversity loss. Furthermore, this data supports preparedness in the community and can be used to identify areas with high wildfire fuel loads. The process used to develop this data, via its reliance on more than 100 community scientists across the region, also increases local knowledge on the focal invasive plant species and their impacts on wildfire risk. Community scientists are also provided with increased community networks and relationships with land managers and scientists.

There are challenges to applying these ESRI apps to land management, however, particularly in cases of limited expert capacity and volunteer coordination. While ESRI's GIS tools have powerful analytical capabilities, they are complex and require professional levels of expertise to take full advantage of their functionality. In the case of this collaborative community science project, the lack of a dedicated GIS professional has hampered comprehensive use of the data gathered. Land managers utilizing similar community science models would likely see more returns if a GIS manager can assist with the program. Similarly, skilled volunteer coordination is an essential element of a successful community science program, even with the support of powerful, user-friendly apps. Collaborators with the Desert Defenders project have seen the most success mapping in cases of: (1) a dedicated and highly trained force of stewards, (2) community scientists led by rangers on joint mapping and removal efforts, and (3) single "champion" volunteers or interns who take the lead in smaller areas.

4.3. EcoFlora

Of the aforementioned nine core elements most often associated with community resilience, community science innately contributes to community resilience most strongly through local knowledge, community networks and relationships, communication, health, governance and leadership, resources, and mental outlook [37]. Community science projects can become community networks, providing the opportunity for people to develop relationships with one another that they may not have had otherwise, promoting social capital, enhancing social cohesion and community trust, and contributing to community resilience [36]. The data, information, and workload contributed by community scientists can be used to shape policy or empower community involvement in local government and leadership, and is at a wider range and frequency than could be accomplished by scientists or land managers alone [53].

Community science can contribute to conservation by directly affecting the conservation science influencing decision-making [54]. As mentioned previously, the project collects a wealth of open-source data and information that can be used by the community, organizations, or land managers. Educational resources, training sessions, and workshops through the project give the community access to and experience with technological and physical tools that exist indefinitely. Empowered with and given access to science knowledge, tools, and experience, communities can be more involved in decision-making and political advocacy, and feel more confident in conservation participation and activities

surrounding urban biodiversity. This contributes to collective and self-efficacy, as well as mental outlook, by providing people with a way to be directly involved in science and be better prepared to respond to disasters such as wildfires. By making contributions that help scientists understand more about urban biodiversity, gaining science knowledge and experience, and contributing to local conservation efforts, EcoFlora project members are building community resilience.

The EcoFlora project has not been without challenges, namely data quality, study area considerations, and sustaining and growing engagement. Data quality can be lacking on the iNaturalist platform. Observations by community scientists can be of poor quality, for example, uploading out-of-focus images or cut flowers in a bouquet. The identification feature of the iNaturalist platform does not require any kind of credentials. This can lead to users making identifications at an exponential rate, simply to increase the number of observations they have identified or to appear more knowledgeable. Other users can make incorrect identifications simply because they are trying to learn and become better at identifying organisms. To alleviate the data-quality challenge, the EcoFlora project has created collateral to guide project members in making quality observations and has asked local experts to assist in monitoring identification accuracy.

When deciding on the study area for EcoFlora, there were multiple factors to consider. The Phoenix metropolitan area is a large and rapidly increasing region that does not have a defined boundary. It consists of numerous cities and towns and has a variety of land uses. Distinguishing urban, suburban, and exurban areas for the boundary was not feasible, while previously created Keyhole Markup Language (KML) files did not exist. Highways and roads can provide clean lines for a boundary, but they can inequitably divide communities and create border vacuums [55]. In creating a study area, EcoFlora sought to include the multiple parks that surround the Valley, be considerate of tribal lands, and not exclude under-resourced communities. A hand-drawn boundary in iNaturalist was created, using the CAZCA study area as a base and keeping these elements and objectives in mind.

Initiating and sustaining engagement is a struggle that many smaller conservation organizations face. EcoFlora is fortunate to have the backing and support of CAZCA, DBG, and the EcoFlora partner gardens. Without this existing support, it would have been substantially more difficult to make the public aware of the project. Even with this support, engaging the community and drawing participants to the project has been challenging, specifically considering the COVID-19 pandemic. It was not possible to host in-person workshops and events that could increase interest and participation in the project with large groups of people. Engagement has been largely virtual, which has presented its own learning curve. When feasible, in-person events with limited attendance (10 or less people) while following pandemic guidelines have resulted in fluctuating attendance. Without the digital distribution of EcoFlora information through iNaturalist, DBG, and CAZCA, along with online technologies such as video conferencing software, social media, and e-newsletter, the project would not have been able to initiate or sustain the engagement that it has.

5. Conclusions

Social media has often been considered a source of increasing challenges to land management of public lands and natural open spaces worldwide, but these tools also have supportive potential which is of considerable importance as natural disasters increase with climate change and resource shortfalls for land managers become more common. Our three case study programs illustrate a variety of ways that land managers can use social media and other online applications (iNaturalist and ESRI FieldMaps) to enhance governance and local well-being. We have demonstrated that each model provides support for (1) conservation activities, (2) land governance and policy changes, and (3) community resilience. In conjunction with this, two of the projects also provided spatial data relevant

for land management via community science efforts that utilized online applications as user-friendly data-gathering interfaces.

While capacity and expertise are necessary to launch ambassadorships and community science, programs that make the best use of social media and online technologies ensure resources can be kept to a minimum. Innovation and the potential for such efforts to alleviate landscape governance and land management resource challenges is considerable. The case studies outlined lend practical support for the application of different kinds of online technologies to the challenges faced by land managers, and also outline models for applying these tools in effective ways. They are shown to provide marketing and outreach that might otherwise be cost prohibitive, while also building relationships and trust between land managers, partner organizations, and the public [16,42,46]. Data on changing conditions is also essential to effective landscape-scale governance and biodiversity conservation efforts, but the temporal and spatial extent of that need can also be prohibitive without community support. Online technologies, particularly phone apps, can facilitate the creation of community science projects that can supply data, while also developing public support and understanding for land managers [28,29].

In conjunction with the various ways in which programs linked with social media and online technologies support land managers directly, these efforts can enhance community resilience to unprecedented changes in the environment and disasters such as wildfires, hurricanes, and pandemics, among others. In particular, of the elements commonly identified across fields as elements of community resilience [37], those that have been found to be positively influenced by these efforts include local knowledge, community networks and relationships, communication, resources, preparedness, and mental outlook. The impacts of social media and app-supported efforts by land managers could be further improved through design and planning that explicitly targets community resilience as a primary objective.

Finally, the challenges outlined in these case studies, as well as the moderate resource needs of these models, can be sourced via collaborative efforts among organizations with common goals. While complex, collaborative efforts facilitate the leveraging of limited but shared resources for the greater good and also enhance the effectiveness of land governance among varied assemblages of stakeholders and constituents [56,57].

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