September 3, 2021

Jennifer Norris
Deputy Secretary for Biodiversity and Habitat
California Natural Resources Agency
1416 Ninth Street
Sacramento, CA 95814

Re: Implementation of Executive Order N-82-20 (30 by 30 Strategy)

Dear Deputy Secretary Norris:

We are writing to provide our initial recommendations regarding the development of the state's 30 by 30 strategy, as it relates to lands and waters in the Inland Desert region. Our groups represent community members and non-profits working throughout the region on issues of conservation and access specific to our region. This coalition has been working for the last six months on shared interests and values.

The letter identifies the many concerns we feel in the Inland Desert, which include the existential and daily threats of climate change, drought and water shortages, logistics centers, mining and other industrial expansion, concern about the protection of our desert public lands "our lungs", fear about the fate of the Salton Sea, habitat loss and fragmentation.

Although our groups are each committed to 30 by 30 as expansively described in E.O. N-82-20, the state's specific commitment to "conserve at least 30 percent of California's land and coastal waters by 2030" must include a commitment to fund and implement the process at the scale and speed necessary to meet this deadline and be grounded in a strong definition of "conserved". As you review this letter, we invite you to consider how the issues we identify can be implemented. The key to a successful outcome is to center the process around equitable values and work in partnership with tribes, federal land managers, local governments, land trusts, and non-governmental organizations (NGOs), such as ourselves, who are working on-the-ground, in the region.

I. Overview

As defined by the California Natural Resources Agency (CNRA), the “Inland Desert Region” consists of Imperial County, eastern parts of Riverside, and most of San Bernardino County. At the outset, we note this definition presents a considerable obstacle to effective science-based land management, as from both ecological and Native cultural perspectives, the inland deserts do not align with the “Inland Deserts” borders defined by CNRA. We feel that effective stewardship of wildlife connectivity, air quality, cultural resources, and similar issues warrant consideration of a larger desert region. Unless told otherwise, ***we include the desert portions of the Sierra Nevada, East sub-ecoregion (including Death Valley) and the greater Western Riverside / San Bernardino County metropolitan area when we refer to the ‘Inland Desert’ region in this letter. We encourage CNRA to do the same when planning holistically.***

Our region includes one of the last intact ecosystems in North America, habitats for endangered species, and California’s largest inland lake. Desert lands provide critical carbon sequestration, dark night skies, opportunities for solitude, critical habitat for plants and animals, and springs and seeps.

Nearly five million people call the Inland Desert Region home. Some of the key communities include Baker, Banning, Barstow, Bishop, Blythe, Brawley, Cathedral City, Coachella, El Centro, Idyllwild, Indian Wells, Indio, Joshua Tree, La Quinta, Lone Pine, Mecca, Needles, Palm Desert, Palm Springs, Shoshone, Thermal, Twentynine Palms, Victorville, and Yucca Valley and the greater San Bernardino-Riverside metropolitan area, among others.

We also note that our region has benefitted from many land-use planning efforts to date, including the California Desert Conservation Area Plan as amended, including the most recent plan amendment, the Desert Renewable Energy Conservation Plan (DRECP) (originally envisioned as a private and public lands plan); the Coachella Valley Multiple-Species Habitat Conservation Plan; the Western Riverside Multiple Species Habitat Conservation Plan; the Upper Santa Ana River Wash Plan in San Bernardino County; the San Bernardino Regional Conservation Investment Strategy (in draft); environmental and conservation elements of the Imperial, Riverside, and San Bernardino Counties’ General Plans; and other local jurisdiction conservation plans. We hope the state’s 30 by 30 process will utilize and build on the successes of these existing conservation plans while creating more durable and expansive conservation for our region.

The State of California cannot begin to establish conservation benefits or achieve other 30 by 30 biodiversity goals unless it addresses immediate threats which include a fundamental underappreciation and misunderstanding of the California desert; coordination with tribal governments for land stewardship; support for the identification, acquisition, and exchange of private lands from willing sellers needed to ensure landscape connectivity between sensitive protected areas; a growing health problem in the region that will only be exacerbated if desert soils are disturbed and not able to perform their natural function as our regional air filters; generational inequity and access issues amongst marginalized communities; and lack of funding to provide resources and funds to implement many of the needed actions detailed below.

Despite the threats and challenges, the State and its communities should remain optimistic. We spend most of the content in this letter dedicated to opportunities for short and long-term actions that if implemented, will contribute to a successful 30 by 30 effort.

Besides our overarching recommendations for the region, this letter also includes a list of public and private lands that merit further protection through the 30 by 30 process **(Appendix A)**.

II. Public Lands in the Inland Desert

The Inland Desert Region includes over 11.6 million acres of some of California's most spectacular public lands and waters. These public lands and waters are part of the most intact and unfragmented ecosystem in the lower 48 states and are of incalculable value to plants, wildlife, and people. Additionally, 2.4 million acres are designated as Important Bird Areas by the National Audubon Society within the Colorado and Mojave Deserts.

Desert natural lands provide multiple values and benefits to our region, including: critically important plants, wildlife habitat and connectivity; clean water; dark night skies; jobs, tax revenue and regional economic well being; carbon sequestration; free or relatively inexpensive recreation opportunities; physical and mental health benefits; and, unparalleled vistas that enchant and enrich the lives of domestic and international visitors and desert residents. These public lands can and should provide public access to hunt, fish and forage for sustainable, healthy food sources according to State and tribal wildlife harvest regulations. Some of these areas hold sacred sites of critical importance to many Indigenous peoples and the CNRA should be mindful to preserve public access to traditional activities like hunting and gathering, which have been practiced on the landscape for thousands of years.

However, many in our communities, including those in the Greater San Bernardino and Riverside County, Eastern Coachella or Imperial Valleys are lacking the access and financial wherewithal to visit and benefit from these places. Much work must be done to increase transit access and improve facilities to make sure these places are available and welcoming for regional community members as much as it is for visitors from afar.

III. Challenges to the People and Environment of the Inland Desert

A. *Threats Related to Air Quality & Carbon*

Portions of the Inland Desert Region experience some of the worst air quality in the state and nation. This is particularly true in the Inland Empire and Eastern Coachella[1] and Imperial Valleys, each of which have census tracks that have been identified as disadvantaged communities by the State of California's CalEnviroScreen. These areas are out of attainment for federal air quality standards and have extremely high cumulative exposure to air pollutants. Factors contributing to this unhealthy air varies by region but primary drivers include vehicular emissions from inland ports and the logistics industry, agriculture, and dust from off-highway vehicles. In Imperial County, the rate of asthma-related emergency room visits and hospitalizations for children ages 0–17 years is double the California state average. The American Lung Association has given Imperial County a failing grade in its annual state of the air report based on high levels of ozone and particulate matter. In the Eastern Coachella Valley and Imperial Valley, air quality and associated air quality-related illnesses will each be impacted as the Salton Sea, the state's largest inland lake, begins to recede, leaving an exposed and emissive dusty shore. Near the Salton Sea, hospitalization rates for children with asthma are already double the state average.

Our desert lands are the lungs for our region -- desert public lands provide tremendous carbon and climate benefits. The Inland Desert (including the Sierra Nevada East region) is known to be responsible for sequestering 10% of carbon **(Appendix B)** in the state of California and imminent research suggests the percentage is higher. Unlike other carbon sinks, disturbing processes supporting below ground sequestration may take generations if not millennia to recover naturally. Furthermore, if disturbed and exposed, recent studies show that desert carbon would be released back into the atmosphere. Desert carbon refugia as well as biological soil crusts that protect soils from erosion should be considered integral to maintaining clean air and as a deterrent to human health complications.

B. Threats to Desert Lands

Despite their irreplaceable values, desert lands are vulnerable to multiple threats including policy loopholes that are exploited or miscategorized in order to circumvent land conservation efforts. One such instance can be discerned in The Dingell Act -we urge the state to support our efforts to remove any ambiguity in the Dingell Act about its aim to permanently protect the California Desert National Conservation Lands. This would entail upholding and reinforcing the intent of the 2009 Omnibus Public Land Management Act and the Desert Renewable Energy Conservation Plan as well as making the National Conservation Lands only revocable by an act of Congress.

Additional threats include:

- climate change;
- habitat loss including diminished or truncated wildlife corridors;
- under-funding from Congress and the State Legislature for management and restoration;

[1] The Eastern Coachella Valley, San Bernardino/Muscoy and El Centro/Heber/Calexico have each been selected by the California Air Resources Control Board as community air monitoring communities under AB 617. The North End of the Imperial Valley was recently nominated as an AB 617 community.

- poorly planned and managed off-highway vehicle uses which can damage habitat and harm air quality;
- ‘trespass grows’ of marijuana;
- poorly-planned urban and suburban development, including subdivision (creation of new parcels) and fragmentation (individual sale of legal parcels);
- development of logistics centers and associated infrastructure;
- industrial development including inappropriately sited renewable energy projects and mining;
- food and water from human settlements subsidizing the Common Raven, leading to higher populations and increased predation on the desert tortoise and other species;
- invasive plant and insect species infestations and nitrogen deposition from air pollution, which facilitates the spread of invasive plant species;
- road building and route proliferation that results in habitat fragmentation;
- illegal dumping;
- misguided sales or trades of public lands that harm conservation efforts;
- illegal theft of plants (e.g., cactus poaching) and animals for profit by commercial enterprises in ways that harm cultural and natural resources[2];
- overgrazing activities associated with ranching; and
- water depletion, including through continued pumping of groundwater in overdrafted aquifers and water diversions.

IV. 30x30 Opportunities for the Inland Desert Region

There is much the state can do, even in the near term and sometimes at relatively little expense, to achieve many of its 30 by 30 goals in the Inland Desert Region.

The recommendations outlined below are integral to the equitable development and deployment of 30 by 30 priorities within the Inland Desert. While developing California’s 30 by 30 strategy, we request that the state:

A. Engage in meaningful government-to-government consultation with tribes.

The greater Inland Desert region is the traditional home of many tribes, including the Agua Caliente Band of Cahuilla Indians, Augustine Band of Cahuilla Indians, Big Pine Paiute Tribe, Bishop Paiute Tribe, Bridgeport Indian Colony, Cabazon Band of Mission Indians, Cahuilla Band of Indians, Colorado River Indian Tribes, Fort Independence Indian Community of Paiute Indians, Fort Mojave Indian Tribe, Fort Yuma Quechan Indian Tribe, Lone Pine Paiute-Shoshone Tribe, Morongo Band of Mission Indians, Pechanga Band of Luiseño Indians, Ramona Band of Cahuilla, San Manuel Band of

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[2] There are increased issues with large-scale removal of plants and animals for commercial uses in the California desert, such as white sage. Removal of plants and animals, usually motivated by profit, causes serious harm to desert cultural and natural resources. However, we want to distinguish this issue from tribal members who harvest plants for traditional uses or hunt on their ancestral lands. Tribal members often have difficulty accessing federal and state lands, and under California law, can face criminalization for accessing their traditional cultural resources. As currently written, California laws and natural resource regulations obstruct the rights of tribal members and indigenous people to practice their traditional hunting, gathering, and fishing rights.

Mission Indians, Santa Rosa Band of Cahuilla Indians, Soboba Band of Luiseño Indians, Timbisha Shoshone Tribe, Torres Martinez Desert Cahuilla Indians, the Twenty-Nine Palms Band of Mission Indians, and the Utu Utu Gwaitu Paiute Tribe.

The state must engage tribes early in this process through formal government-to-government consultation. Based on the outcomes of the consultation processes, the state should develop specific goals and recommendations for how the 30 by 30 process will respect tribal sovereignty and support tribes in their efforts around renaming landmarks, land return, and management and co-management of lands and resources. This also includes active efforts to consolidate land that might be checker-boarded with federal and state lands and we encourage CNRA to use the 30 by 30 process to consolidate and return lands to tribes. We also encourage CNRA to develop other funding programs so that tribal governments have the staffing necessary to engage in consultation and other aspects of the 30 by 30 process.

Tribes' environmental stewardship and beneficial management and cultural practices have proven to be sustainable within our region, and these practices should likewise be supported. We encourage CNRA to work with tribes to promote the application of traditional ecological knowledge in the management of lands and waters and support tribal efforts to steward land. We also note that tribes who wish to harvest plants for traditional uses or hunt on their ancestral lands have difficulties gaining access to their ancestral lands and can face criminalization for accessing their traditional cultural resources. Barriers to harvesting or other access to cultural resources (e.g., gates, closed roads, and requirements for obtaining permits) are compounded by inconsistent co-management arrangements between tribes and state and federal land agencies. These barriers and complications combine to make gathering difficult. We encourage CNRA to seek ways to work with tribes, state agencies, land trusts, and federal land managers to promote access to federally- and state-managed lands for tribes seeking to access traditional cultural resources and gathering sites.

B. Work with environmental justice communities to develop 30 by 30 strategies to benefit their communities. Whenever possible, give these stakeholders decision-making power.

Although the Inland Deserts Region has incredible public lands, parks and open spaces, these places are not accessible to many of the communities that actually live in our region, particularly communities of color in the Inland Empire, Eastern Coachella and Imperial Valleys.

1. Work with all Californians - especially Black, Indigenous, and People of Color (BIPOC) and equity leaders - on a strong, meaningful, and measurable definition of "equity."
2. Due to historical patterns of racial exclusions, discrimination in human settlement, and the violent removal of indigenous peoples from their ancestral homelands, communities of color are three to four times more likely to live in nature-deprived areas. We have seen this firsthand in the Inland Empire and Eastern Coachella Valley. We encourage the state to engage the communities most impacted by the loss of access to nature as early as possible in the process of conservation, do so consistently, and create feedback loops that showcase how their input is being

considered. New and expanded green spaces that meet the needs of Black, Indigenous, and People of Color communities are an opportunity to address the historical policies and programs that have perpetuated these inequities. We encourage CNRA to conduct community-level needs assessments and collaborate with local community-based organizations (who in many cases have already done this work).

3. Uplift youth-led, organizing leaders and Black, Indigenous, and People of Color communities in the greater San Bernardino-Riverside metropolitan area such as the city of San Bernardino, which currently ranks as having the worst ozone pollution in the nation and suffers from more than 100 days of “bad air” each year.
4. Transportation access is a major issue in much of our region, especially the Imperial and Eastern Coachella Valleys. Throughout the region there are few opportunities to access National Parks and other natural spaces without a car. CNRA should invest in transit to trails and other programs which can make desert lands more accessible for communities who live here.
5. Partner with community-based organizations and leaders in farmworking communities in the Eastern Coachella and Imperial Valleys, which face severe barriers to transportation, recreation, housing, employment, health, and a safe environment. Political will is high and youth activism is deeply embedded in local culture. We encourage CNRA to meet with community leaders, including youth to develop 30 by 30 solutions. Also, engage with farmworking communities to fund sustainable farming practices and increase equitable food production and distribution practices.
6. The State should also consider addressing cost barriers by eliminating or reducing park fees for disadvantaged communities at Anza Borrego, Salton Sea and other state parks and work with federal land managers to do the same for lands they manage. A potential option for reducing cost barriers may include a dedicated time frame during park operating hours that offers a reduced rate for entry and use fees, which should be specially marketed to disadvantaged communities to encourage increased access.
7. CNRA should improve the public process for 30 by 30 by advancing procedural equity through varied outreach opportunities, including setting meetings on weekends or after work, when possible, as well as continuing to provide high-quality translation of multiple languages. Similarly, establish outreach timelines that empower all communities, including those that are identified as disadvantaged or marginalized, by implementing approaches that consider the varied capacities to engage in the 30 by 30 process by diverse groups. Finally, establish measurable outcomes to ensure that all stakeholders are operating from a shared understanding about 30 by 30 terms, processes, and outcomes. Honor both Indigenous and cultural knowledge of local groups to ensure the generational and lived experiences of historically oppressed groups are reflected in the 30 by 30 policy and approach.
8. Provide new state and local protected lands in underrepresented, under-resourced, and urban areas. These include providing greater access and amenities at the North and South ends of the Salton Sea to make it a welcoming space for communities that live there.

9. Engage with desert land trusts working to create spaces and programming for communities of color to connect with the land including providing opportunities for increased technical and financial capacity to do their work and acquire lands near urban areas, which in many cases are much more expensive.
10. Engage desert stakeholders in conversations about process, equity, public and environmental health and development related to the Salton Sea and "Lithium Valley."
11. Funding must also be included to build adequate infrastructure that meets the needs of communities, to properly maintain green spaces, and to ensure the safety and welcoming inclusion of all visitors including signage and programming in multiple languages.

C. *Establish and support climate resiliency and conservation efforts in the Inland Deserts region.*

1. Consider opportunities to protect and restore important habitat, migration corridors, and connectivity as well as public access and equity, when identifying priority lands. It is particularly important to protect lands that include ecosystem types that are under-represented in the current network of protected lands such as riparian areas and microphyll woodlands.
2. Work with federal and state agencies, including the Department of Defense (DOD), tribes, NGOs, desert land trusts, and private landowners to protect, improve or restore connections between large blocks of habitat and reduce or eliminate barriers to movement for wildlife both now and under future conditions when natural communities may shift due to climate change impacts. In particular, the state should protect the wildlife connectivity areas identified in the Desert Renewable Energy Conservation Plan and the California Desert Biological Conservation Framework.
3. Adopt a definition of "conserved" that is limited only to those lands and waters that are permanently protected from industrial development. "Conserved" areas must be established with enduring measures, support connected and intact habitats and thriving biodiversity, contribute to climate resilience and equity, provide ecosystem services, and be managed so that their natural character, resources, and functions exist for current and future generations. Examples of such areas on public lands include designated wilderness areas, wild and scenic rivers, national monuments, state preserves, wildlife refuges, and national and state parks. Examples of such lands on private lands would be those permanently under conservation easements or deed restrictions and with that disallows destructive development, and is coupled with funding for conservation management in perpetuity.
4. Collaborate with local, state, federal, and private interests to secure public access to and improve conservation of scattered and isolated tracts of public land. In the Inland Desert Region, it is especially important to secure access to and improve the management of isolated Bureau of Land Management (BLM) parcels that are currently inaccessible to public use and difficult to manage because they are surrounded by private lands.

5. Identify lands at the Salton Sea for consolidation into conservation ownership and management to streamline and simplify Salton Sea management and project implementation
6. Work with the DOD to identify and protect key habitat areas through the Readiness and Environmental Protection and Integration Program (REPI) and to continue to partner with the DOD and other partners on the application to create a “Sand to Sea” Sentinel Landscape.
7. Work with agencies and desert land trusts to identify potential donors, sellers or traders of strategically important private lands that are near or adjacent to existing public lands that, once exchanged, can be protected or placed under a conservation easement.
8. Resolve the longstanding issues of the management of State Lands Commission parcels, especially where they exist as inholdings among other public lands. Ensure that the lands are conserved and connected to other protected parcels to the maximum extent possible.
9. Promote and support nonprofits and schools educating and connecting the general public and communities of color to the desert and providing educational programming around desert conservation.
10. Enact policies that do not disturb below-ground carbon sequestration and storage. California’s hot deserts contain a large pool of inorganic carbon in the form of calcium carbonate (caliche), derived from biological processes. Because of carbon’s potential to remain sequestered in mineralized form for millennia, it is often considered that carbon stored underground in caliche does not affect greenhouse gases, however, this mineralized carbon will be released back into the atmosphere if weathered upon exposure when disturbed.
11. Create and/or fund a California Desert Conservancy. The California Desert comprises one-quarter of the state yet has only one small regional conservancy. For example, CNRA should applaud efforts such as Assembly Bill 1183, a legislative effort to support conservation funding through bond proposals and the state budget.

D. *Halt destructive development projects that hurt people and lands*.

We urge the state to use its permitting and enforcement power to stop projects that destroy our natural resources and in most cases do not benefit our communities long-term. We also encourage the state to work with local governments to ensure that many of these locations, fought over for years, could instead be converted into community green and open spaces and preserved for their historical-cultural values.

1. *Mining and Exploration:* We urge the state to oppose industrial-scale mining and exploration projects that would contribute to the destruction of undeveloped lands, habitat connectivity, and cultural and biological resources. California has 331,569 mining claims on public land. Of these claims--San Bernardino, Inyo, and Imperial are the most active counties in California. As one example, Conglomerate Mesa, on desert public lands in Inyo County is currently threatened by industrial-scale gold

mining, which involves constructing miles of new road and 120 drill holes across ancestral tribal lands. If the mine becomes a reality, the developers would also need to pump millions of gallons of water from underground aquifers already suffering from a mega-drought and depleting the groundwater that feeds springs across the desert, leaving cyanide-laced pools behind. In addition, the developer may opt to transport water into the area adding significant stressors to the sensitive environment. Conglomerate Mesa is located between two existing federal wilderness areas, which help provide landscape-level habitat connectivity and high elevation climate refugia for plant and animal species. The area has some of the highest concentrations of cultural and heritage resources found in the Inland Desert region. We urge the state to adopt regulations through the California State Mining and Geology Board to prohibit open-pit mining

2. *Cadiz Water Project*: Cadiz, Inc. proposes to export 50,000 acre-feet of water annually from a fossil water aquifer underlying protected lands in the eastern Mojave Desert. Peer-reviewed studies show that the aquifer feeds at least five springs in Mojave Trails National Monument, which are important not only for wildlife but to the cultural continuity of local Native peoples. The State Lands Commission should apply the most stringent possible standards in assessing harm Cadiz or any similar project poses to the desert's natural and cultural resources as it fulfills its duties under SB 307, passed into law in 2019.
3. *Eagle Crest Pumped Storage:* An energy company has proposed a destructive and water-intensive pumped storage facility in the southeast region of Joshua Tree National Park-an area home to golden eagles, desert tortoises, bighorn sheep, and important prehistoric and historic resources, from Native American archaeological sites to General Patton's training camps to a World War II-era mine. The California Public Utilities Commission (CPUC) should reject this project and the state should advocate to the Department of the Interior (DOI) to transfer this land to the National Park Service (NPS) as an addition to Joshua Tree National Park. Further, the state should oppose any legislative efforts to advance this project at the CPUC.
4. *Sprawl Development*. Our region continues to see an increase in irresponsible sprawl housing which harms the desert ecosystems either through direct habitat conversion or indirectly, through demand for natural resources such as groundwater or increased air pollution. These proposals, such as Paradise Valley, Coral Mountain Resort, and the Thermal Beach Club, also cause gentrification impacts to surrounding communities, without providing much-needed housing or recreational space for the communities that live here. A sustainable housing solution that does not stress the environment and the community should be implemented.
5. *Logistics center expansions and inland ports.* Oppose expansion of logistics centers and further industrialization of the Inland Desert region that pose a threat to air quality, connective lands, biodiversity, and human quality of life.
6. *Utility scale renewable energy development.* Encourage the development of roof-top solar distributed electrical generation, not utility-scale developments that destroy intact desert land. Support the CPUC to adopt incentives in the upcoming consideration of NEM 3.0 to encourage the development of a resilient, distributed,

electrical grid. A recent resolution adopted by the CPUC and lobbied for by investor-owned utilities would 'not encourage' rooftop solar and would severely reduce the credit for rooftop-generated electricity.

E. *Existing opportunities to implement 30 by 30 in the Inland Desert region.*

1. The Salton Sea, California's largest inland lake, is located in both Riverside and Imperial Counties and is a key migratory stopover for over 375 bird species on the Pacific Flyway. With its marine, freshwater, desert, wetland and agricultural habitats, the Salton Sea provides habitat for hundreds of birds and wetland species, including several that have been listed as endangered or sensitive by the U.S. Fish and Wildlife Service (USFWS). The Salton Sea will be receding through a confluence of drought and rural to urban water transfers. There is an opportunity to reimagine a smaller, sustainable Salton Sea with open spaces and other facilities that benefit the diverse and varied communities at the Salton Sea, driven by community input.
2. Create opportunities for collaboration with other state programs in the region, including: the Salton Sea Management Program (SSMP), the Urban Greening program, and sustainable farming initiatives (to name a few).
3. Work with community-based organizations in the Salton Sea region to support community-led efforts to design open spaces and prioritize funding these efforts.
4. Support community-led efforts on public lands, including the community-led effort to create a management plan for the Mojave Trails National Monument and Sand to Snow National Monument.
5. Work with CDFW (California Department of Fish and Wildlife), BLM, California Energy Commission, Counties, key stakeholders, and the public to ensure that energy development on public and private lands does not undercut 30 by 30 goals. Concrete steps CNRA could take include: funding the completion of the private lands portion of DRECP as originally envisioned, and directing renewable development to brownfields and other degraded and fragmented lands, most of which were identified on private lands. The state should consider supporting the private land planning efforts of (1) the California Energy Commission's land planning efforts, (2) the creation and implementation of Regional Conservation Investment Strategies (RCIS) (e.g., the current San Bernardino County effort and the draft Antelope Valley RCIS), (3) the creation and implementation of Natural Communities Conservation Plans (NCCPs) (e.g., the Apple Valley NCCP), (4) working with the CPUC to enact policies to require load-serving entities to procure renewable energy projects that are sustainably sited and avoid impacts to desert plants and wildlife, and (5) preventing further loss of microphyll woodlands to energy development.
6. Actively engage in land management planning processes and similar public engagement opportunities, particularly those undertaken by the BLM, USFS (U.S. Forest Service), and U.S. Fish and Wildlife Service (USFWS) to ensure that those processes are resulting in land conservation consistent with 30 by 30 goals, including the California Desert Biological Conservation Framework. One example of

a specific need for state engagement is in the BLM's upcoming decision regarding the fate of the North of Kramer Development Focus Area. This area is critical to the survival of the imperiled Mohave ground squirrel and should be set aside into a conservation designation. It is also important that CNRA engage in the development of Resource Management Plans for the Mojave Trails and Sand to Snow National Monuments in San Bernardino County and in the BLM's effort to implement the John D. Dingell Conservation and Recreation Act of 2019 in the Vinagre Wash Special Management Area in Imperial County.

7. Urge Congress and the State Legislature to craft and pursue new protection bills for California's public lands and waters in the Inland Deserts region without adversely affecting existing recreation activities or interfering with critical infrastructure.
8. Help federal agencies identify key public lands and waters that deserve protection or special management, including areas for potential new or expanded wildlife refuges due to their superlative natural, cultural, or other values or because they are needed to increase climate resiliency or to provide for habitat connectivity.
9. Protect, improve, or restore connections between large blocks of habitat that are already protected and reduce or eliminate barriers to movement for wildlife both now and under future conditions when natural communities may shift due to climate change impacts. In addition to investments in land protections, CNRA should also make much-needed investments in wildlife road crossings, structures like bridges and underpasses, that allow animals to safely cross even the busiest of motorways and access suitable habitats. These investments should be targeted on roadways that cross South Coast Wildlands' A Linkage Network for California Desert's identified linkages.
10. Urge Congress to appropriate funding levels for the BLM, USFS, USFWS, and the National Park Service (NPS) that will enable the agencies to effectively manage and protect California's federal public lands and waters and provide for equitable, well-planned, and sustainable access and recreation.
11. Provide adequate and sustainable funding for California state parks, wildlife refuges, and other conserved lands, including providing sufficient resources for the California Department of Fish and Wildlife to fulfill its ambitious and essential mission.
12. Help local governments implement 30 by 30 at the local level. Specific actions CNRA could take include: educating county supervisors and other local elected officials and land use planners through presentations and discussions about the importance of 30 by 30 and encourage them to support related conservation and access enhancement efforts, providing template language, resources for zoning, policies and other tools that will advance 30 by 30 goals, providing grant programs to Counties and local governments for implementing these efforts, similar to the CEC's program for renewable energy elements. CNRA could also support and create new land-use planning tools such as the SoCal Greenprint for local governments and provide incentives that reduce local land-use decisions that create habitat fragmentation and reduce new development into fire-prone landscapes, wildlife

connectivity areas, and important and rare habitats. CNRA should also promote and support existing and planned Regional Conservation Investment Strategies and Natural Communities Conservation Plans.

13. Work with state agencies, federal land managers, and Congress and the State Legislature to ensure that fees for camping and other activities on state and federally managed lands are not socio-economically prohibitive and that these spaces are welcome to all and have culturally appropriate programming. As an example, the communities by the Salton Sea State Recreation Center, (an arm of the California State Park system) located in Mecca, California, have an annual average income of $32,395 with a poverty rate of 39.34% making it difficult to use their expendable income (if any) for the park entrance fee. The Salton Sea State Recreation Center also has physical barriers and guards that make the space unwelcome to migrant community members.
14. Collaborate with academia, state, and federal agencies to enhance the funding for below-ground carbon sequestration studies; carbon in California's deserts can be distributed between one meter (3 feet) and 60 meters (197 feet) deep, below depths commonly surveyed.
15. Identify areas with outstanding outdoor recreation values during land-use planning to enable advocates and others to further leverage the importance of recreation as a means for advancing conservation values, as well as managing recreational impacts and supporting recreational experiences, equitable access, and the outdoor recreation economy.

F. *Develop Policies and Programs to Support Sustainable Agriculture*

Many people in the Imperial and Eastern Coachella Valley are employed in the local economy through agricultural labor. Many farmworker communities, particularly in the Eastern Coachella Valley experience water contamination/lack of drinking water, poor air quality, prohibitive cooling bills, poor housing conditions and poor air quality. Imperial County, the winter vegetable basket for the world, has the highest rate of child hunger in the state, with 40% of children experiencing food insecurity. Food insecurity and a lack of access to fresh food is also an issue for the Inland Empire. Synthetic pesticides and fertilizers play a key role in increasing greenhouse gas emissions and in depleting soil health and therefore the ability of the soil to absorb nutrients, including carbon and nitrogen, as well as contaminating water and air--harming farmworkers, community members and wildlife.

Many of these farmlands also provide important habitat for birds and other species. Specifically, the agricultural matrix in Imperial Valley provides critical habitat for many birds, including habitat for 70% of the state's burrowing owl population, a California species of special concern. Farmland conversion for solar has led to the rapid decline of burrowing owls in the Imperial Valley. We recommend the following:

1. Conserve farmland in the Imperial Valley, which is a high-value for burrowing owls and other bird species. This can be done through permanent conservation or agricultural easement.
2. Support wildlife and habitat connectivity through various agricultural incentives like the California Waterfowl Delayed Wheat Harvest Incentive Program. This program provides subsidies for farmers to delay the harvest of winter wheat and other small grains to give wild duck nests in their fields time to hatch before harvest.
3. Incentivize more biological and socially sustainable farmlands and pest management for the region through transitions to agroecology and regenerative agriculture, farms for farmworkers, the eradication of synthetic pesticides, Indigenous agriculture, and other practices.
4. Support community gardens (Huerta del Valle is a great example in the Greater San Bernardino area), farms for farmworkers, and other opportunities to connect and create land ownership for communities of color throughout the region.

G. *Conserve Land to Expand the Local Economy*

The Inland Desert Region depends on the health of its native ecosystem to maintain its vibrant tourism industry, which is key to the economy of the Inland Desert. Millions of tourists visit the national, state parks, and other natural resources in the Inland Desert Region every year creating direct and indirect economic benefits to the region. Although much of this visitation is to desert National Parks, which are a huge local economic driver, visitation to other protected areas on federal lands as well as Anza Borrego State Park, the Sonny Bono National Wildlife Refuge, and the Salton Sea Recreation Area also bring jobs and local economic benefits.

- In 2018, 787,000 park visitors spent an estimated $46.5 million in local gateway regions (including the communities of Victor Valley, Barstow, and Baker) while visiting Mojave National Preserve. These expenditures supported a total of 588 jobs, $22.2 million in labor income, $36.7 million in value-added, and $58.8 million in economic output in local gateway economies surrounding Mojave National Preserve.
- In 2018, 2.9 million park visitors spent an estimated $146 million in the local gateway regions (including the towns of Joshua Tree and City of Twentynine Palms) while visiting Joshua Tree National Park. These expenditures supported a total of 1,830 jobs, $71.9 million in labor income, $122 million in value-added, and $196 million in economic output in local gateway economies surrounding Joshua Tree National Park.
- The outdoor recreation economy in Congressional districts 8, 32, and 51 (all of which are completely in or overlap with, the Inland Deserts region) generate $4 billion in annual spend by regional residents

V. Community Priorities in the Inland Desert

We will close by offering our collective responses to the questions developed for the 30 by 30 CNRA regional workshops.

Question 1: What are the habitats and species most important to you?

We strongly support efforts to ensure the future viability of all species of plants and wildlife that are native to the Inland Desert Region as defined by the CNRA. Some of the many key wildlife species of concern in the region include the desert tortoise, LeConte's thrasher, banded gecko, desert iguana, chuckwalla, regal horned lizard, Gambel's quail, desert rosy boa, Mojave patchnose snake, northern Mojave rattlesnake, Coachella Valley and Mojave fringe-toed lizards, bighorn sheep, gila monster, burro deer, greater roadrunner, Mohave ground squirrel, Amargosa vole, desert pupfish, burrowing owl, short-eared owl, golden eagle, American white and brown pelicans, eared grebes, mountain lion, bobcat, grey fox, coyote, desert kit fox, Sonoran pronghorn, desert bighorn sheep, and giant desert hairy scorpion, among a long list of others.

We also strongly support current efforts to reintroduce the Sonoran pronghorn to the Inland Desert Region and envision a day when the Mexican wolf might be reintroduced as well.

A few of the key plant species include the iconic Joshua tree, ironwood, creosote, fairy duster, brittlebush, desert holly, white burrobush, pinyon pine, juniper, California fan palm, silver cholla, Mojave prickly pear, beavertail cactus, barrel cactus, and pencil cholla, among others.

A few of the key habitats that are critical to sustain over time in the Inland Desert Region include all springs, seeps, creeks and rivers, microphyll woodlands, shoreline, wetlands, and deep water habitat at the Salton Sea, the riparian habitat everywhere in the desert including along the Colorado River including the northernmost reaches of the Delta, desert playa, surficial habitats such as cryptobiotic soil crusts and desert pavement, pinyon-juniper woodland, Joshua tree woodland, cactus yucca scrub, dunes, creosote bush scrub, washes, fan palm oases, blackbrush scrub, and below ground mycorrhizae and caliche networks that sequester carbon among a long list of others.

Question 2: Thinking about this region, what nature-based climate solutions are important to you?

- Improved protections for and management of public lands, waters and natural and working lands
- Salton Sea management projects that advance community access to nature, expedite habitat restoration, protect public health, and improve water and air quality
- Parks and amenities for communities in unincorporated areas
- Management of intact desert habitat for carbon sequestration, airborne particulate matter control and public health
- Equitable and inclusive access for all to public lands and waters
- Permanent conservation easements with management funding

- Strategic acquisition and conservation of key lands and waters
- Improved stewardship of private lands and waters
- Improved local land use planning that avoids impacts to important natural lands that provide carbon sequestration, biodiversity protection, and equitable access and that creates more livable and walkable communities for all.

Question 3: Thinking about recreation and access in this region, what types of places are important to you?

- Federal, state, and local public lands and waters. It is critically important that public lands and waters be managed in such a way as to be available for the enjoyment of all people consistent with law, policy, and sustainability principles.
- Lands and waters that are currently popular for recreation but management is under-resourced.
- Protection of lands and creation of parks prioritized in communities with limited access to nature/are most impacted by over-development and pollution burdens (for example: at the Salton Sea). The visioning and planning for recreational opportunities and amenities should be co-created with communities, who should be engaged at every stage of their development.
- Parks and open spaces that replace development or brownfields in urban communities.

Question 4: What is working in this region to conserve lands and/or coastal waters, implement nature-based solutions to climate change, or increase equitable access to nature and its benefits?

- Management as state or national park units
- The National Wilderness Preservation System
- National Wildlife Refuge system
- California State Recreation Areas
- The National Wild and Scenic Rivers System
- California Desert National Conservation Lands
- National Monuments
- Conservation easements
- Private land acquisition efforts by federal land management agencies
- Land trust efforts to acquire, manage and/or restore important natural lands.
- Improved practices on private lands
- Improved agency planning and coordination, such as with the California Desert Conservation Area Plan as amended including the DRECP and the Coachella Valley Multiple Species Habitat Conservation Plan
- Growing interest in traditional ecological knowledge-based methods of land management
- Improvements in community engagement around the Salton Sea Management Plan
- Leave below-ground soils intact so that the natural process of carbon sequestration storage takes place and carbon capture is not released into the atmosphere

- Working with the DOD through their Readiness and Environmental Protection Integration (REPI) program and to create a "Sand to Sea" Sentinel Landscape

What is working in the Inland Desert Region to address climate change is:

- The protection of natural landscapes in parks, wilderness, refuges, national conservation lands, BLM's Areas of Critical Environmental Concern (ACECs), easements, and other land use designations and conservation protections
- Improved practices on private lands
- Efforts at the state and federal levels to reduce carbon emissions
- Maintenance of desert soils and soil crusts undisturbed as carbon sinks
- Maintaining wildlife connectivity so that desert wildlife can freely move to adapt to changes in climate

What is working in the Inland Desert Region to increase equitable access to nature and its benefits is:

- New acquisitions that offer public access
- The maintenance of existing recreation facilities such as trails and campgrounds.
- Efforts to keep recreation activities on public lands free or affordable.
- Ongoing efforts by several schools, nonprofits, and others throughout the Inland Desert Region to introduce underprivileged youth to the wonders of nature and the outdoors.
- Campaigns to make public transportation a more effective and accessible means of travel to open space areas

Question 5: The State of California is committed to conserving 30% of its lands and coastal waters by 2030. What does conservation mean to you?

"Conserved" areas must be established with enduring, non-administrative measures such as legislation or durable conveyance of conservation easements. They must support thriving biodiversity, contribute to climate resilience, provide ecosystem services, and be managed so that their natural character, resources, and functions exist for current and future generations.

Question 6: Please describe the greatest challenges to conserving lands and/or coastal waters, implementing nature-based solutions to climate change, or increasing equitable access to nature and its benefits?

The greatest challenges to conserving lands in the Inland Desert Region are:

- Lack of adequate and sustained funding from both state and federal sources
- The threat of industrial development on both public and private natural lands
- The threat of renewable development on previously undisturbed desert lands
- Stopping the proliferation of illegal cannabis sites on undisturbed desert lands
- Poorly planned housing development that fragments landscapes.

- Climate change
- Lack of political will
- Inadequate enforcement of existing laws protecting wildlife
- Inadequate enforcement against illegal activities that impact natural and cultural values, including illegal cannabis operations and illegal off-highway vehicle use.
- The potential undermining of the DRECP conservation commitments through the BLM approving one-off development projects that require the BLM to change agreed-upon conservation management actions through a project-specific plan amendment (e.g, the Oberon Solar Project)

The greatest impediments to using nature-based solutions to address climate change in the Inland Desert Region include:

- A lack of sustained funding from both state and federal sources
- Inadequate planning and coordination among land managers, scientists and stakeholders
- Lack of political will
- Utility-scale solar projects sited on undisturbed desert land
- A misunderstanding by various government agencies about the carbon sequestration process taking place below ground desert soils

The greatest impediments to increasing equitable access to nature and its benefits include:

- Lack of engagement and collaboration driven by legacies of environmental racism and socio-economic marginalization of communities
- A lack of sustained funding from both state and federal sources
- Inadequate planning and coordination among land managers and the public
- Lack of political will
- Diminished or non-existent resources and capacity to meaningfully engage communities around local priorities for conservation and build local collaboration for successful projects
- A lack of appreciation for and misunderstanding of the cultural and spiritual aspects of marginalized communities

Question 7: What does long-term success look like for nature-based climate solutions in this region?

- Sustained funding for the nature-based efforts to address climate change.
- Changes in working and natural land and water management practices that reduce impacts to the climate.
- An intact and interconnected system of conserved lands, waters and habitats is accessible to all
- Reduction in habitat fragmentation from illegal route proliferation by off-road vehicles

- Salton Sea habitat and dust suppression projects are completed as part of the 10-year plan, with robust support for operations, monitoring, and maintenance, and there is a successful long term plan for sustaining them and a plan for the Salton Sea as a whole
- Below-ground carbon sequestration science is understood and funding is provided to research the additional benefits from caliche and mycorrhizae functions **(Appendix C)**

Question 8: What does success look like for 30 by 30?

- A responsible and thriving regional tourism economy with job provisions
- All native populations of plant and wildlife species in the region are ensured long-term population viability.
- An integrated system of conserved habitat areas provides recreation that is appropriate to the values for which the areas are conserved and renewal for residents and visitors while supporting a vibrant tourist economy
- Public land managers are provided with the resources they need to steward and provide equitable access to our lands and waters.
- Strong incentives exist to promote improved conservation measures.
- Agriculture and farming are sustainable, equitable practices
- Our Inland Desert communities sustainably thrive and recognize that strong conservation and equitable access benefits all.
- Human-caused climate change is reversed and prevented.
- Reduction in habitat fragmentation from illegal route proliferation by off-road vehicles
- The desert is viewed by the mainstream public as a miraculous bio-diverse hotspot that provides a long list of benefits to the ecosystem and the humans within it.

V. Equitable Progress Through 30 by 30

We look forward to working with you to implement Governor Newsom's ambitious effort to ensure that all Californians will enjoy access to a healthy and climate-resilient environment in which biodiversity and people thrive. Thank you for taking our recommendations into consideration. We welcome future opportunities to collaborate on this important work.

Sincerely,

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(continued on next page)

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APPENDIX A

30 by 30 Inland Deserts

List of Recommended Areas in Need of Further Protections

(content begins on next page)

30x30 Inland Desert Region

List of Recommended Areas in Need of Further Protections

1	Chemehuevi Valley	MAP	The ecosystem here is intact, and provides needed landscape connectivity between Mojave Trails and the Havasu, Chemehuevi, Turtle, Stepladder and Whipple Mountains Wildernesses as well as the Colorado River.
2	Lands south of the San Jacinto Wildlife Area	MAP	These lands would be a natural extension of the San Jacinto Wildlife Area a key reserve of the Riverside County Multi-Species Habitat Conservation Plan.
3	Santa Margarita River Watershed	MAP	Temecula Creek buffer lands connecting Vail Lake Resort, Oak Mountain identified corridors and crossings.
4	Mojave River Corridor	MAP	Provides critical habitat in the Mojave Desert, along with an important corridor for habitat connectivity and migration. Much of the river corridor is currently unprotected, though some significant stretches are in public ownership.
5	Granite Mountains Corridor		An important corridor between semi-protected lands, but currently unprotected. Most of it is privately owned & could be vulnerable to further development. Within the pending Apple Valley Habitat Conservation Plan.
6	Chino Creek Watershed	MAP	The basin drains 218 square miles of mostly urban, heavily populated land. Restoration and protection could enhance nature recreation for underserved populations, maintain woodland areas and restore heavily polluted waters.
7	Santa Ana River Watershed	MAP	Multiple jurisdictions and ownership. Will need to partner with other organizations and review mapping and possibilities for one of the longest rivers in SoCal.
8	San Jacinto and Whitewater River Watersheds		Extensive watersheds that feed into large urban areas and are controlled with channels and dams and lakes. These rivers need review and mapping by partners and extensive study.
9	San Bernardino National Forest	MAP	Although the SBNF is public land, the administration of this land and the many private inholdings within and adjacent to the SBNF merit protection.
10	Salton Sea	MAP	Explicit policies are needed to foster win/win, multi-benefit projects to manage the Salton Sea going forward and to ensure adequate inflows of water and operational funding for long-term sustainability. Prioritize acquisition of water rights to conserve & stabilize the shrinking Salton Sea. Protect & restore ecology, wetlands around perimeter, & implement dust control projects. Establish new laws to limit diversions.
11	Conglomerate Mesa	**MAP**	This area is threatened by industrial-scale gold mining with active mineral explorations underway. The area contains some of the last remaining stands of healthy, reproducing Joshua Trees in the Inland Desert and California Department of Fish and Wildlife have engaged with the Bureau of Land Management to raise concerns about threats to habitat. The Mesa is located between two existing federal wilderness areas, which help provide landscape level habitat connectivity and high elevation climate refugia for plant and animal species. The area has some of the highest concentrations of cultural and heritage resources found in the Inland Desert region.

12	Chuckwalla Bench		800,000 Acres. ACEC at risk of development. One of the largest intact ecosystems with immense ecological value. Between the Chocolate and Chuckwalla Mountain Ranges, stretching between Joshua Tree NP and Mexico's Yuma border. Rare desert plants include the Munz Cholla cactus, the Mecca Aster, and the Orocopia Sage. The Chuckwalla Bench is critical habitat for the threatened Agassizi's Desert Tortoise and the endangered Sonoran Pronghorn (expected to be re-introduced in coming years). It is prime habitat for the burro deer, which is a type of mule deer that has adapted to desert living. It also contains unusually high densities of birds, reptiles, and mammals. Other natural features of note include microphyll woodlands, volcanic spires, broad washes, cactus gardens, and stunning desert and mountain views.
13	Smoke Tree Valley	https://goo.gl/maps/voUGQXEd2qLY5ohF8	
14	Amargosa Basin	MAP	
15	Squints Ranch, Lake Arrowhead		80 Acres. Unique location and part of a wildlife corridor with endangered, threatened and sensitive species like the Southern Rubber Boa, California Spotted Owl and the San Bernardino Flying Squirrel.
16	Boy Scouts Property, Lake Arrowhead		2,078 Acres. Unique location and part of a wildlife corridor with endangered, threatened and sensitive species like the Southern Rubber Boa, California spotted Owl and the San Bernardino Flying Squirrel.
17	Blue Ridge, Lake Arrowhead		39.8 Acres. Unique location and part of a wildlife corridor with endangered, threatened and sensitive species like the Southern Rubber Boa, California spotted Owl and the San Bernardino Flying Squirrel.
18	Concordia, Lake Arrowhead		81.86 Acres. Unique location and part of a wildlife corridor with endangered, threatened and sensitive species like the Southern Rubber Boa, California spotted Owl and the San Bernardino Flying Squirrel.
19	Music Camp, Arrowbear		86.81 Acres. Unique location and part of a wildlife corridor with endangered, threatened and sensitive species like the Southern Rubber Boa, California spotted Owl and the San Bernardino Flying Squirrel.
20	Wyatt Property, Arrowbear		70.75 Acres. Unique location and part of a wildlife corridor with endangered, threatened and sensitive species like the Southern Rubber Boa, California spotted Owl and the San Bernardino Flying Squirrel.
21	Simon Mountain, Arrowbear		8.8 Acres. Unique location and part of a wildlife corridor with endangered, threatened and sensitive species like the Southern Rubber Boa, California spotted Owl and the San Bernardino Flying Squirrel.
22	Powderhorn Ranch, Running Springs		80 Acres. Unique location and part of a wildlife corridor with endangered, threatened and sensitive species like the Southern Rubber Boa, California spotted Owl and the San Bernardino Flying Squirrel.
23	Keller Meadows, Running Springs		20 Acres. Unique location and part of a wildlife corridor with endangered, threatened and sensitive species like the Southern

			Rubber Boa, California spotted Owl and the San Bernardino Flying Squirrel.
24	Silurian Valley	MAP	Silurian Valley - This valley is primarily public lands managed by the BLM and connects the western boundary of the Mojave National Preserve to the south end of Death Valley National Park through the Baker Sink. While SR 127 goes through this area, once outside of the small town of Baker, the highway is the only sign of human development in the expansive viewshed....amazingly undisturbed landscape with dunes, playas, bajadas, mountains, permanent surface water and full of wildlife.
25	Panamint Valley	MAP	Panamint Valley is currently undisturbed by development. Located directly west of Death Valley National Park and managed primarily by BLM, it is a classic basin and range experience that supports desert wildlife connectivity and is key in maintaining the integrity of the Mojave desert landscape.
26	Bat Cave Buttes, Dos Palmas Conservation Area		Known as a roosting habitat for California leaf nose bats *Macrotis California,* and a significant habitat area for Desert Lilies *Hesperocallis undulate.* A Survey of the area is recommended to determine the presence of Townsend's Big-eared Bats *Corynorhinus townsendii* -an S2 Imperiled species.
27	Coral Mountain Resort, La Quinta		400 Acres in the City of La Quinta. This project threatens to negatively impact this area's existing cultural, ecological, and recreational features. Coral Mountain itself is a cultural and historically rich space, where Native American petroglyphs, intact honey mesquite hummocks, and the ancient Lake Cahuilla Shoreline are visible and accessible to our community. The expected irresponsible development of this area would damage these irreplaceable assets and that access to outdoor recreational opportunities on public lands (Coral Mountain, Boo Hoff Trail, and the Santa Rosa Wilderness) would be limited.
28	Tipton Road, Palm Springs (Adjacent to Hwy 111 and I-10 Conservation Area and within the Whitewater Floodplain Conservation Area)		The Whitewater Floodplain is a critical wildlife corridor that facilitates movement through Snow Creek, the Whitewater Floodplain, and Whitewater Canyon. It also provides critical habitat for endemic species.
30	California Desert Connectivity		This functional network of connected habitats are essential to the continued existence of California's diverse species and natural communities in the face of both human land use and climate change. The components of this landscape are large enough and connected enough to meet the needs of all species that use them. As habitat conditions change in the face of climate change, some species ranges are already shifting and wildlife must be

			provided greater opportunities for movement, migration, and changes in distribution. This concept is exemplified in this California Desert Connectivity map by the California Department of Fish & Game. https://wildlife.ca.gov/Conservation/Planning/Connectivity Land acquisition requires partnerships between governmental agencies and desert land trusts

APPENDIX B

CLIMATE MITIGATION IN CALIFORNIA:
THE IMPORTANCE OF CONSERVING CARBON IN DESERTS

(content begins on next page)

Science Brief

Climate Mitigation in California:

The importance of conserving carbon in deserts

As climate change continues to accelerate, it is essential to protect natural habitats that act as carbon sinks. When these areas are developed and disturbed, additional carbon is released into the air and the plants and soils in those ecosystems are impacted, reducing their ability to absorb and store carbon. Studies around the world have shown that desert ecosystems can act as important carbon sinks. With desert ecoregions comprising 27% of California, protecting this biome can contribute to securing carbon stores in the state. By limiting development, excessive OHV use, livestock grazing and other activities that disturb desert soils, the state can help ensure these carbon reserves stay in the ground and out of the atmosphere.

Quick take

- Desert ecosystems provide important carbon storage functions now and in the future given climate change.
- Conserving California deserts can help ensure that the stored CO^2 stays in the ground.
- Key results include:
  - Inland deserts account for 10% of the state's total stored carbon.
  - 7% of carbon-rich areas in California deserts may already be impacted by human activities.
  - Ensuring sufficient desert representation in conserved areas will protect unique species assemblages and ecosystem services.

Carbon Capture in Deserts

There are several ways in which deserts store carbon. To start, desert plants store carbon in their biomass just as other plants do; through photosynthesis, plants take in CO_2 from the air and convert that into tissue. Many desert plants also have important relationships with underground fungi: roots bond with these fungi in a mutually beneficial relationship. As part of this relationship, the plants transfer carbon to the mycorrhizae, which also store carbon. The majority of stored and sequestered carbon, however, is in soils. Plant or animal excretion and decomposition releases some carbon, which reacts with calcium in the desert soil to create calcium carbonate crystals. Since some desert plants' roots grow to over a hundred feet, these crystals, called caliches, can be deep underground. Caliches build into larger chunks over time and create carbon sinks. Additionally, when the root fungi die, they leave behind their waxy coating, which aggregates and helps keep carbon in the soil. For their storage and sequestration potential, arid-semiarid soils are considered the third largest global pool of carbon (Emmerich 2003).

Read more about the desert carbon storage process here: http://www.desertreport.org/?p=2270

California Carbon Sinks

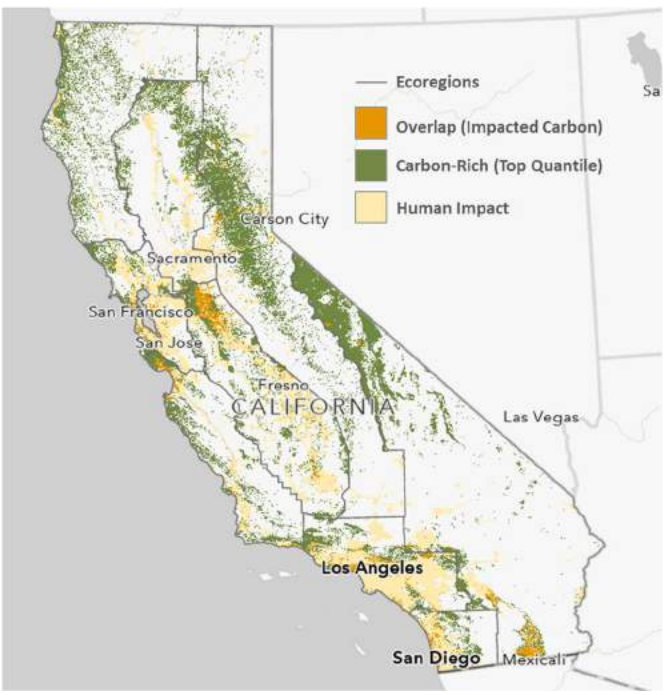
The most conclusive evidence of California desert carbon storage potential comes from a 10-year study in the Mojave Desert at the Nevada Desert Free-Air CO_2 Enrichment Facility (NDFF). This study compared plots of desert with current CO_2 levels to plots with projected 2050 CO_2 levels. To do this, they piped extra CO_2 over the plots. At the completion of the study, the researchers compared the carbon between the plots with current CO_2 levels and those with projected CO_2 levels. They found that the plots that received extra carbon were able to store significantly more carbon than those that received current carbon levels. This indicates that as atmospheric CO_2 levels rise, deserts will have increased capacity to sequester in response to projected elevated atmospheric CO_2. Deserts store 9.7% of California carbon and based on the NDFF experiment, and this amount may increase with climate change. A report by the National Parks Service shows that Death Valley and Joshua Tree National Parks and the Mojave National Preserve were within the top 10 park units with the highest annual net ecosystem carbon balance.

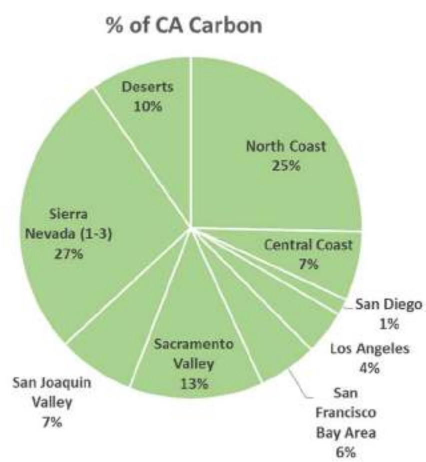
Read the full scientific article for this experiment here: https://doi.org/10.1038/nclimate2184

Results

The data indicate that 27% of lands within the state of California fall within desert ecoregions (Inland Desert and Sierra Nevada-East). These lands alone account for nearly 10% of the total carbon stored in the state. Importantly, the top carbon-rich locations in deserts are less impacted by human activity compared to other ecoregions: 7% overlap with areas of higher human footprint compared to nearly one quarter of carbon-rich areas in the San Joaquin Valley. Currently, 42% of carbon-rich areas in desert regions fall into areas managed for conservation. An additional 35% fall on public lands managed for multiple uses (including extractive activities). Based on these results, California deserts sequester and store a significant amount of the state's carbon. Though desert environments have relatively low sequestration on a per area basis, they represent a large proportion of the state's area and are relatively undisturbed by human activity.

Carbon can be stored in a number of different reservoirs. Here we analyzed total ecoregion carbon in above- and belowground biomass and in soil (Soto-Navarro et al. 2020). We compared the top carbon-rich areas for each ecoregion with human footprint metrics and the protected areas database of the U.S.





Map highlighting carbon-rich areas (top 20%) within each ecoregion and current coincidence with higher human disturbance. Sierra Nevada – East was combined with the Inland Desert ecoregion to represent California's deserts as a singular unit.

Recommended Actions

Given their carbon storage capabilities, conservation of large, intact desert areas could have a high return on investment for climate mitigation. Decision-makers will need to account for desert ecosystems in short- and long-term conservation planning efforts to ensure the persistence of these ecosystem services under future climate change scenarios. Great opportunity exists for desert protections on public lands, but some carbon-rich areas could benefit from private lands conservation, especially around the Salton Sea. Particular care should be taken in recognizing Death Valley (Sierra Nevada – East sub ecoregion) as a desert ecosystem that is unique and separate from others in the Sierra Nevada ecoregion. Failing to do so results in underestimation of Death Valley's carbon storage potential, which has been noted in other works. Finally, local stakeholders, Tribes and desert communities should be part of the decision-making process to ensure that those groups disproportionately impacted by conservation (or other) efforts in this ecoregion are well represented.

Questions?
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APPENDIX C

NOTES ON MODELS OF CARBON DYNAMICS FOR THE CALIFORNIA DESERTS

(content begins on next page)

Notes on Models of Carbon Dynamics for the California Deserts

Prepared By Michael F. Allen, Ph.D., Distinguished Professor Emeritus,
Department of Microbiology and Plant Pathology, UC Riverside

Production of organic Carbon ($C_{organic}$) is generally low in hot desert ecosystems. Net primary production in the Mojave desert generally ranges from 10 to 30gC/m^2/y (Rundel and Gibson 1996), with a pool of 0.9 to 1.1kgC/m^2 (Evans et al. 2014). Photosynthesis is limited by temperature and moisture, and decomposition can remain high. Q_{10} values for RuBP Carboxylase is generally credited as a bit over 2 for ten degree increments between 10 and 40^{o}C. Above 30^{o}C, rates of photosynthesis decline rapidly. In deserts, however, soil respiration rates indicative of enzymatic activity can remain high up to 60 to 70^{o}C (Cable et al. 2011). For this reason, C in desert ecosystems has been overlooked or even criticized as a crucial element in global and regional models.

Importantly, there are reports of very high rates of net ecosystem exchange of C (e.g., Xie et al. 2009, Wohlfahrt et al. 2008). These have been criticized as being unreasonable (Schlesinger and Amundson 2019), but no one has provided an alternative explanation for the measured values. While scientists continue to study the patterns and mechanisms of $C_{organic}$ in deserts, we know that California deserts have been accumulating inorganic C ($C_{inorganic}$) for millennia (Schlesinger 1986). While some measurements of the rates of input are controversial, including localized, temporal values equal to those of forest ecosystems (e.g., Schlesinger et al. 2009, Schlesinger and Amundson 2019), ***a large pool of stored C has the potential to be lost through anthropogenic disturbance and exposure***. The mechanisms of C dynamics in desert ecosystems are outlined here with a focus on southern California.

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Xie, J. X., Y. Li, C. X. Zhai, C. H. Li, and Z. D. Lan. 2009. CO2 absorption by alkaline soils and its implication to the global carbon cycle. Environmental Geology **56**:953-961.

What is Caliche?

Caliche is a layer of calcium carbonate ($CaCO_3$) formed between the soil surface, and accumulating at the depth to which water will percolate carrying calcium (Ca) and to which roots will respire CO_2. CO_2 from respiring roots and microorganisms, plus atmospheric CO_2, dissolves in rainwater forming bicarbonate HCO_3^- and hydrogen ions (H^+). Using the free Ca, the equilibrium reaction results in $CaCO_3$, and the $CaCO_3$ crystals precipitate, until the next storm, when the reaction reoccurs and percolates the dissolved $CaCO_3$ in solution down to that storm's depth.

Caliche forms in bajadas below mountains comprised of high concentrations of Ca, particularly basalts (mineral CaO) and silicates ($CaSiO_3$) and limestone $CaCO_3$ formed under the oceans and pushed up geologically, along with its derivatives, dolomite (with added Mg) and marble, limestone's metamorphic derivative. Weathering of well-known mountain ranges, including the Alps and the Himalayas, yields Ca. When in semi-arid to arid regions, deep layering of $CaCO_3$ forms, such as in most of Mediterranean Europe, and the deserts of the southwestern US and northwestern Mexico. As much C in the form of CO_3 is sequestered in arid to semiarid soils as in plant organic C mass globally, and there remains a large "missing sink of C" somewhere in terrestrial ecosystems.

Despite the large amount of $CaCO_3$ sequestered over the past several thousand years, three assumptions contribute to a view among decision-makers that this C can be ignored in the quest to understand C fluxes between the biosphere and the atmosphere. These are three assumptions that pose serious limitations to global carbon modeling and are at least contributors to the large gaps remaining in closing the global C models. These are: (1) $CaCO_3$ is patchily distributed globally and not easily mapped, (2) that the processes are geological and, because the dominant form is inorganic ($CaCO_3$), it is a geological and not biological process. Therefore, no accounting need be undertaken using ecosystem models. And (3), there is an assumption that the rates of transformations and loss are on a geological time scale and not relevant to global change models.

Given that approximately 40% of the increase in atmospheric CO_2 driving global climate change is due to land use change (compared with 60% from fossil fuel burning), it is critical to understand the nature of the largest single terrestrial C pool, especially since much of it is in desert ecosystems.

1) How much and where is Carbon in California deserts?

Surface soil $CaCO_3$ is distributed widely, but in patches throughout the desert. In the surface layers, we can see, for example large swaths in the southern California (SoCal) deserts, where as much as 5% or more of the surface soil is $CaCO_3$ (Fig 1).

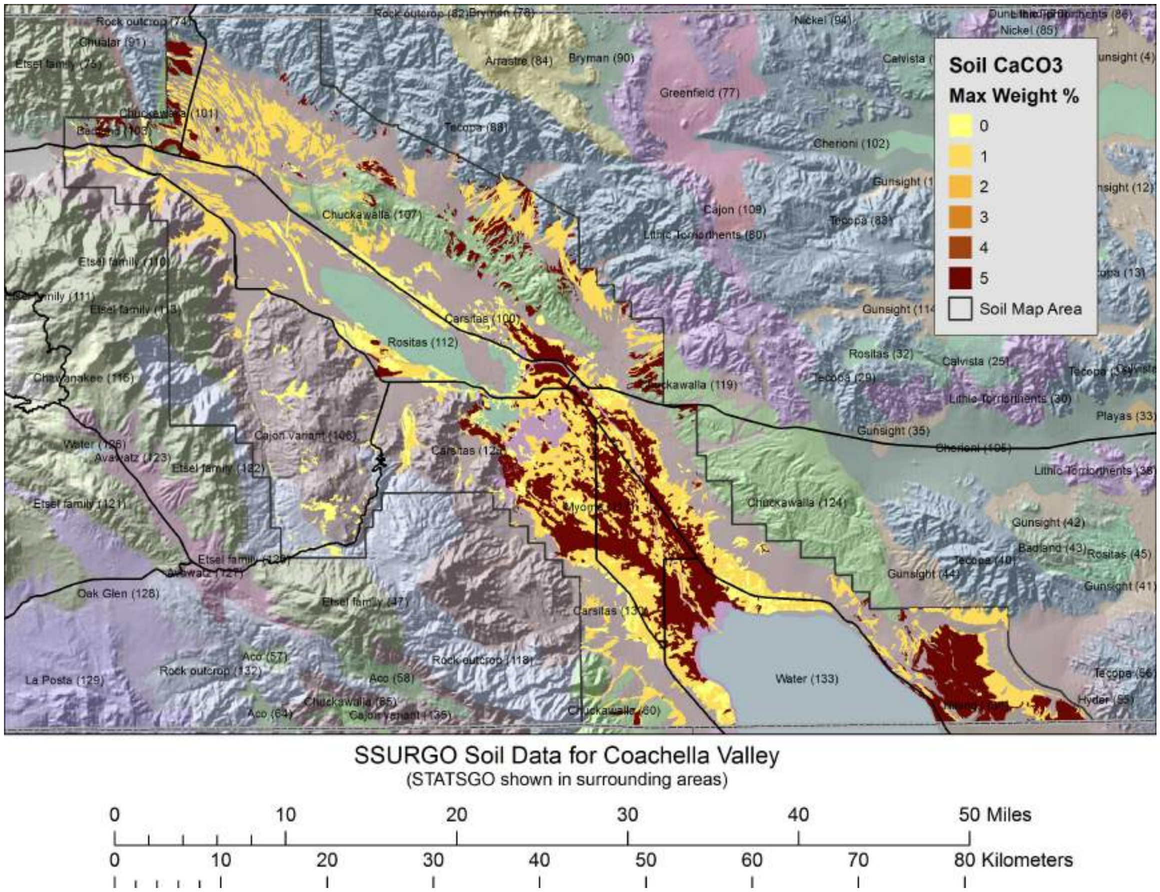

Figure 1. USDA NRS high resolution SSURGO map for surface soil $CaCO_3$, adding the STATSGO data for areas surrounding the Coachella Valley, information from (https://www.nrcs.usda.gov/wps/portal/nrcs/detail/soils/survey/office/ssr12/tr/?cid=nrcs142p2_010596). Map created by the Center for Conservation Biology, UCR.

Schlesinger (1985) found that at depths in the Chuckwalla Valley of greater than a meter, as much as 12% was $CaCO_3$, or between 30 and 70kg/m^2 of $CaCO_3$; or between 4 and 8.4kg $C_{inorganic}/m^2$, or as much C as is stored in mixed grass prairie as soil organic C.

Schlesinger, W.H. 1985. The formation of caliche in soils of the Mojave Desert, California. *Geochimica et Cosmochimica Acta* 49: 57-66.

Other C forms may also be critical in desert ecosystems. Garvie (2006) reported an accumulation of 2.4g $C_{inorganic}/m^2/y$ under saguaro cactus accumulating as much as 40g $C_{inorganic}/m^2$, through the production and release of oxalic acid. The importance of oxalic acid rests not only in and of itself, nor its role in P (phosphorus) nutrition of plants (Jurinak et al. 1986), but in an ability to lead to $CaCO_3$, or caliche accumulation (discussed below).

Garvie, L.A.J. 2006. Decay of cacti and carbon cycling. *Naturwissenschaften* **93,** 114–118. https://doi.org/10.1007/s00114-005-0069-7

It is important to get a better handle on the C distributions and exchanges of both organic and biologically-derived inorganic forms. ***Clearly more extensive surveys of desert C are needed to know how much is actually sequestered.***

2) Do the processes occur only in geologic time scales and, because the dominant form is inorganic ($CaCO_3$), can we ignore this sequestered carbon because it is a geological and not a biological process? In essence, what is the time scale?

Bioweathering by fungi and lichens, and even by many plants, commonly occurs initially in the California desert mountains, resulting in a source of Ca downslope to the bajadas. The biogeochemical pathways provide for a continuous dance between Ca and atmospheric CO_2 across the landscape from the mountain tops to the desert floor, where C is biotically converted to a form, $CaCO_3$ that can be sequestered. However, this form also can be rapidly weathered upon exposure.

The BioGeoChemical Pathways for Biologically-derived Inorganic C.

1) CO_2 (atmospheric) -> $C_6H_{12}O_6$ (photosynthesis): plants, lichen algae, cyanobacteria

2) $C_6H_{12}O_6 + O_2$ -> $H_2C_2O_4$ (bioweathering): lichen fungi, plants, mycorrhizal fungi

3) Ca + $H_2C_2O_4$ -> CaC_2O_4 (calcium oxalate production): desert crusts, rhizosphere, mycorrhizosphere

4) CaC_2O_4 ->Ca + CO_2 (C source, degradation): bacteria, fungal exoenzymes

5) $CO_2 + H_2O$ -> HCO_3^- (bicarbonate formation): root and microbial respired CO_2

6) Ca + HCO_3^- (in solution) <-> $\mathbf{CaCO_3}$ + H^+

As the soils dry, the $CaCO_3$ precipitates, and upon layering, creates a caliche layer.

7) If exposed, with rainfall, $CaCO_3 + H^+ + O_2$ <-> $CO_2 + H_2O$ + Ca

8) Ca + HPO_4^- -> $CaPO_4$, $CaSO_4$ (gypsum)

cycle back to step 1 and step 4.

Description of Steps: It is important to remember that equilibrium does not equal stasis. Each time $CaCO_3$ goes into solution, some of the $CaCO_3$ dissolves into Ca + CO_2 + H^+, with a potential for CO_2 to be released back to the atmosphere. This is a mechanism whereby Ca moves from the mountains into the bajada, and then deeper into the bajada.

1) CO_2 (atmospheric) -> $C_6H_{12}O_6$, or $C_{organic}$ (photosynthesis): plants, lichen algae, cyanobacteria

Photosynthesis and primary production is well understood, and I will not further elaborate. However, it is important to note that photosynthesis is carried on from the tops of desert mountains to the desert floors in plants and desert crusts. These sources of organic C inputs should never be ignored.

2) $C_6H_{12}O_6 + O_2$ -> $H_2C_2O_4$ (bioweathering): lichen fungi, plants, mycorrhizal fungi

Fungi and bacteria produce oxalic acid, among others including citric acid, carbonic acid, and nitric acid. These acids, especially oxalic acid, in particular, allow the fungi of lichens and the mycorrhizal fungi of plants to acquire P from etched rock surfaces (e.g., Gadd et al. 2014).

Gadd, G.M. et al. 2014. Oxalate production by fungi: significance in geomycology, biodeterioration and bioremediation. Fungal Biology Reviews 28: 36-55. https://doi.org/10.1016/j.fbr.2014.05.001.

3) Ca + $H_2C_2O_4$ -> CaC_2O_4 (calcium oxalate production): desert crusts, rhizosphere, mycorrhizosphere

Once arriving at the bajada, oxalic acid is also produced by a wide variety of organisms. Cacti produce high concentrations (Franceschi and Nakata 2005). Many of the fungi in desert crust lichens, but also other biotic crusts produce them. Ectomycorrhizal fungi, such as associated with oaks and pines, produce these acids (e.g., Allen et al. 1996) and even the arbuscular mycorrhizal fungi, formed with the majority of desert perennial plants, form Ca-oxalates as a mechanism, when combined with increasing CO_2 respired within the mycorrhizosphere, to obtain limiting P (Jurinak et al. 1986, Knight et al. 1989).

Allen, M.F. C. Figueroa, B.S. Weinbaum, S.B. Barlow, and E.B. Allen. 1996. Differential production of oxalates by mycorrhizal fungi in arid ecosystems. Biology and Fertility of Soils 22: 287-292.

Franceschi, V.R. and P.A. Nakata. 2005. Calcium oxalate in plants: formation and function. Annual Review of Plant Biology 56: 41-71.

Jurinak, J.J., L.M. Dudley, M.F. Allen & W.G. Knight. 1986. The role of calcium oxalate in the availability of phosphorus in soils of semiarid regions: a thermodynamic study. Soil Science 142:255-261.

Knight, W.G., M.F. Allen, J.J. Jurinak and L.M. Dudley. 1989. Elevated carbon dioxide and solution phosphorus in soil with vesicular-arbuscular mycorrhizal western wheatgrass. Soil Science Society of America Journal 53: 1075-1082.

4) CaC_2O_4 ->Ca + CO_2 (C source, degradation): bacteria, fungal exoenzymes. Once Ca-oxalate is formed, like any organic material, there are both fungi and bacteria awaiting to use it as a carbon source (Morris and Allen 1994, Gadd et al. 2014).

Morris, S.J. and M.F. Allen. 1994. Oxalate metabilizing microorganisms in sagebrush steppe soils. Biology and Fertility of Soils 18: 255-259.

5) CO_2 + H_2O -> HCO_3^- (bicarbonate): root and microbial respired CO_2

Once rainwater or groundwater reaches the location where respiration occurs, whether from roots or microbes, bicarbonate is formed. This can be in the surface, or tens of meters deep (see model discussion below). It is important to note that while atmospheric CO_2 is increasing (from 310ppm in 1950 to 410 today), soil CO_2 can be many thousands of ppm, and we have measured over 2,500ppm at the Boyd Deep Canyon Reserve (see below).

6) Ca + HCO_3^- (in solution) <-> ***$CaCO_3$*** + H^+

The critical step in Carbon Sequestration!

In a comprehensive synthesis, Mike Rowley, in Lausanne, Switzerland, and his colleagues showed that the Ca-oxalate pathway concentrates Ca temporally and spatially, where C is sequestered through oxalotrophy through free Ca coupled with the high concentrations of HCO_3^-, forming $CaCO_3$ (Figure 2).

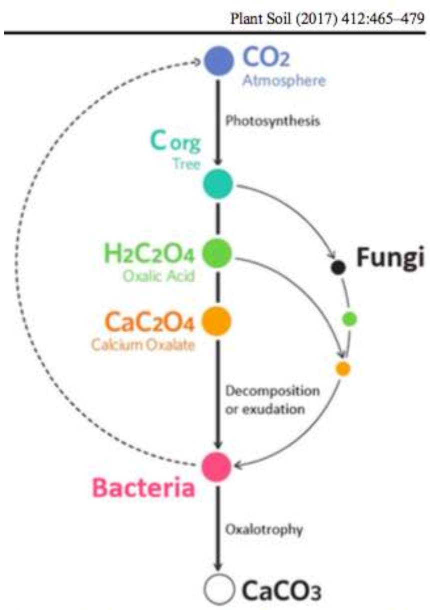

Fig. 1 A simplified model of the Oxalate-Carbonate Pathway (OCP), a process that transfers carbon dioxide from atmosphere to secondary calcium carbonate. As described by Cailleau et al. (2014), the process commences when a calcium oxalate producing species (Tree) organically sequesters carbon during photosynthesis (Corg), converting it into oxalic acid and then calcium oxalate. Once released from organic material during decomposition or as exudes, calcium oxalate is subsequently catabolised by oxalotrophic bacteria (Bact.), converting one mol as carbonate and releasing another as respired carbon dioxide. Fungi also assist in the process by either breaking down oxalic rich matter and depositing calcium oxalate for catabolism by bacteria, or by fungal oxalotrophy

Figure 2. A model showing biotically-controlled CO_2 sequestration focused on the Yucatán Peninsula, from Rowley et al. 2017.

Rowley, M.C., H. Estrada-Medina, M. Tzec-Gamboa et al. 2017. Moving carbon between spheres, the potential oxalate-carbonate pathway of Brosimum alicastrum Sw.; Moraceae. *Plant and Soil 412*: 465-479.

Time Scales:

In our efforts to better understand the time scales of C dynamics, we undertook two types of studies. First, we analyzed the $\delta^{18}O$ signals (Delta-Oxygen-18 is an indication of groundwater/mineral interactions) of caliche across the Coachella Valley. These values showed that caliche was dynamic (Allen et al. 2013). This conclusion was collaborated by a subsequent study in the Mojave desert (Mills et al. 2020).

At Deep Canyon, my research group further re-ran the SLIC model (see model discussion below) using our empirical CO_2 sensor data to determine the $CaCO_3$ in solution (Allen et al. 2013, Swanson 2017, Swanson et al. in preparation). Importantly, soil CO_2 can reach as high as 2,500ppm, as compared with atmospheric CO_2 of 395ppm (during the measurements), as soil respiration increased following precipitation events. $CaCO_3$ in solution tracked the CO_2 and H_2O. As soils dried out, some of the $CaCO_3$ in solution again precipitated forming new caliche deeper in the profile. However, eddy covariance measurements show a large CO_2 flux from both undisturbed soils and from sites with no measureable organic C (Allen et al. 2013, Swanson 2017).

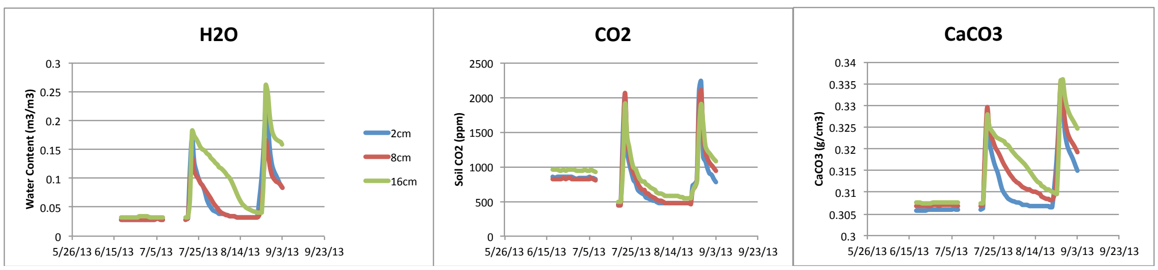

Figure 3. Daily time scales of soil water, CO_2 and modeled solution $CaCO_3$ (SLIC model) following a precipitation event at Boyd Deep Canyon in July through September of 2013 (Allen et al. 2013, Swanson 2017).

Allen, M. F., G. D. Jenerette, L. S. Santiago. 2013. Carbon Balance in California Deserts: Impacts of Widespread Solar Power Generation. California Energy Commission. Publication number: CEC-500-2013-063.

Swanson, AC. 2017. Disturbance, Restoration, and Soil Carbon Dynamics in Desert and Tropical Ecosystems. PhD. Dissertation. University of California-Riverside.

7) If exposed, with rainfall, $CaCO_3 + H+ + O_2$ <-> $CO_2 + H_2O + Ca$

$\delta^{18}O$ ratios show that in surface soils, $CaCO_3$ continually turns over (Allen et al. 2013, confirmed by Mills et al. 2020). We do not know where, or how much Ca is redistributed with erosion, but there is considerable wind erosion of Ca, especially as calcium sulphate (Frie et al. 2019).

Allen, M. F., G. D. Jenerette, L. S. Santiago. 2013. Carbon Balance in California Deserts: Impacts of Widespread Solar Power Generation. California Energy Commission. Publication number: CEC-500-2013-063.

Frie, A.L. A.C. Garrison, M. V. Schaefer, S. M. Bates, J. Botthoff, M. Maltz, S. C. Ying, T. Lyons, M. F. Allen, E. Aronson, and R. Bahreini. 2019. Dust Sources in the Salton Sea Basin: A Clear Case of an Anthropogenically Impacted Dust Budget.

Environmental Science & Technology 53 (16), 9378-9388 DOI: 10.1021/acs.est.9b02137

Mills, Jennifer, Laura Lammers, and Ronald Amundson. 2020. Carbon Balance with Renewable Energy: Effects of Solar Installations on Desert Soil Carbon Cycle. California Energy Commission. Publication Number: CEC-500-2020-075

8) Ca + HPO_4^- -> $CaPO_4$ (bound inorganic P, $CaSO_4$ (gypsum)

Even though in equilibrium, Ca tends to attach to -CO_3 but some can bind to phosphate or sulphate (forming gypsum), move in solution downstream, or even blow via wind erosion (Frie et al. 2019).

Frie, A, A Garrison, M Schaefer, S Bates, J Botthoff, M Maltz, S Ying, T Lyons, MF Allen, EL Aronson, R Bahreini. 2019. "Dust Sources in the Salton Sea Basin: A Clear Case of an Anthropogenically Impacted Dust Budget." Environmental Science & Technology. 53(16):9378-9388. doi: 10.1021/acs.est.9b02137.

(3) What we are missing is an overall synthesis of the rates of CO_2 exchange across the California deserts, both from landscape models, and from local validation measurements. These are crucial for a broad overview of C fluxes in the desert.

The Models: One modeling concept uses the assumption that the rates of transformations are on a geological time scale and not relevant to change models. These are the models that should be used and tested.

DayCENT: Parton, W. J., M. Hartman, D. Ojima, and D. Schimel. 1998. DAYCENT and its land surface submodel: description and testing. Global and Planetary Change 19:35–48.

The Century model was designed to estimate long-term soil C accumulation. DayCENT is a version of Century using a daily time-step to better understand short-term C dynamics. It is the most sophisticated model available appropriate to generate long-term understanding of soil C. But there are limitations that require a better incorporation of concepts described below and the data and model inputs specific to California's deserts.

Rao et al. 2010 used DayCENT for studying the impacts of Nitrogen deposition on Net Primary Productivity (NPP -or how much CO2 vegetation takes in during photosynthesis minus how much CO2 plants release during respiration) in deserts, mostly as related to fire. But there is one distinct limitation to the current generation of DayCENT models: the ability to access groundwater. During a year dominated by native forbs, simulated production was 20-40g C/m^2, but measured production was 60-80gC/m^2.

Rao, L.E., E.B. Allen and T. Meixner. 2010. Risk-based determination of critical nitrogen deposition loads for fire spread in southern California deserts. Ecological Applications 20: 1320-1335.

Using DayCENT, Joshua Tree National Park, the accumulated SOM-C (soil organic matter-carbon) ranged from 668 to 916g/m2, depending on N deposition. This compares with measurements ranging up to 2,000g/m^2 (USDA 2013).

United States Department of Agriculture, Natural Resources Conservation Service, and United States Department of the Interior, National Park Service. 2013. Soil survey of Joshua Tree National Park, California. (Accessible online at: http://soils.usda.gov/ survey/printed_surveys/)

Much of these production differences were probably due to accessing of deep-water sources. Furthermore, using DayCENT, we do not know inorganic C, the largest pool of C in California deserts.

Regional expertise for DayCENT- Leelia Rao CARB, G. Darrel Jenerette UCR

Limits to DayCENT 1: Deep water.

Our primary concern was an inability in the model to incorporate deep roots into organic C accumulation due to the model not integrating deep root dynamics. Many shrubs in the microphyll woodlands have deep roots and microbial associations (e.g., Virginia et al. 1986). Roots reaching deep and especially to groundwater level, allow the plant to continue growing and fixing carbon well into the dry periods (Ogle et al. 2004). For example, creosote bush sends horizontal roots through the shallow upland soils to find cracks in caliche. Then they dive deep, obtaining a large fraction of their water from within and below caliche layers (Ogle et al. 2004). In our estimates of deep-water use (Allen unpublished data), as much as 60 to 90% of the plant water in microphyll woodland plants came from the groundwater. Moreover, roots and the mycorrhizosphere (the region around a mycorrhizal fungus colonizing plant roots) contribute to increasing atmospheric CO_2, increasing the partial pressure pushing bicarbonate concentrations (see SLIC modeling below). These plant mycorrhizospheres are producing CO_2 for the creation of HCO_3^-, binding with Ca to form $CaCO_3$ deep in the profile at unknown rates.

Ogle, K., R.L. Wolpert, and J.F. Reynolds. 2004. Reconstructing plant root area and water uptake profiles. Ecology 85: 1967-1978.

Virginia, R.A., M.B. Jenkins, and W.M. Jarrell. 1986. Depth of root symbiont occurrence in soil. Biology and Fertility of Soils 2: 127-130.

In a California conifer-hardwood forest, we initially used DayCENT to characterize NPP (Allen et al. 2014). We also measured ET (EvapoTranspiration, or transpiration plus evaporation) and NEE using eddy-flux measurements (Michael Goulden data, UC Irvine) and our sapflow measurements of water transport. DayCENT failed to identify the extended summer water flux because it did not have a mechanism to acquire deep water (Figure 4).

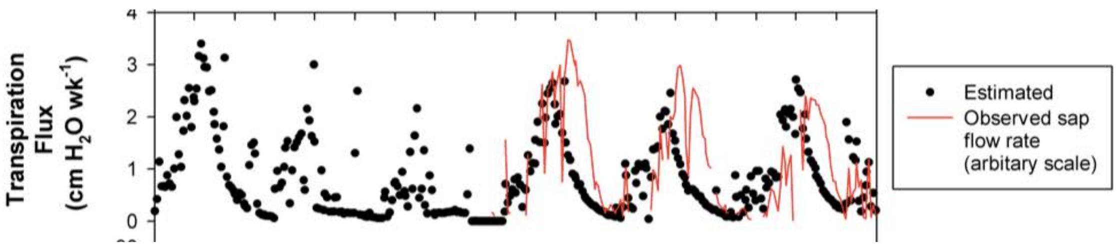

Figure 4. Kitajima and Allen-output from a model run from 2005-2010, from Allen et al. 2014, showing the comparison in Transpiration flux measurements with DayCENT modeling (dots) versus measured sapflow rates (red line). The lag in transpiration (which affects CO_2 fluxes) does not show in DayCENT as there is no provision for access to deep-water sources. As long as there is transpiration, there is fixation.

Allen, M.F., K. Kitajima, R.R. Hernandez. 2014. Mycorrhizae and global change. Pp. 37-59: in M. Tausz, N.E. Grulke (eds). Trees in a changing environment. Springer-Plant Sciences, Dordrecht, The Netherlands.

Regional Expertise Eddy Covariance calibration measuring NEE: Ray Anderson USDA Salinity Lab (UCR campus), G. Darrel Jenerette UCR

HYDRUS: Simunek, J., M. T. Van Genuchten, and M. Sejna (2005), The HYDRUS-1D software package for simulating the one-dimensional movement of water, heat, and multiple solutes in variably-saturated media, University of California, Riverside, Research Reports, 240.

For this reason, we shifted to HYDRUS 1D to study seasonal water flux and the role of deep water. Again, we compared modeled output to eddy covariance flux measurements and measured isotopic composition (δD = delta-deuterium, or hydrogen-2, and δ^{18}O, or delta-oxygen-18) to confirm the sources of the water (Kitajima et al. 2013). We modified the HYDRUS 1D to acquire the deep moisture. By making these changes in the model, we could account for the added growing season length and summer water use. Given that the water isotopic composition of many desert species shows that a large fraction to the majority of the plant's water was from groundwater, making these adjustments was critical to overall C budgets, and will be invaluable for any estimates of C fluxes in desert soils.

Kitajima, K., M.F. Allen and M.L. Goulden. 2013. Contribution of Hydraulically Lifted Deep Moisture to the Water Budget in a Southern California Mixed Forest. Journal of Geophysical Research- Biogeosciences 118: 1561-1572

Suarez, D. L., and J. Šimůnek (1993), Modeling of carbon dioxide transport and production in soil: 2. Parameter selection, sensitivity analysis, and com- parison of model predictions to field data, Water Resources Research 29: 499–513, doi:10.1029/92WR02226.

Regional expertise for HYDRUS: Jirka Šimůnek - UCR Environmental Sciences (author of Hydrus), Tom Harmon UC Merced.

Limits to DayCENT 2: Inorganic C

The inorganic C (C_i) in California deserts is very patchy, but can be quite high. Schlesinger (1985) undertook landmark studies in the alluvial plain outwash from the Eagle Mountains and the Coxcomb Mountains. He measured between 30 and 70 kg of $CaCO_3/m^2$, or between 4 to 8.4 kgC/m^2 of inorganic C or C_i. This would place the soil C in the range of C in the middle of the Great Plains, and even the lower end of the C-rich temperate forest soils.

Schlesinger, W. H. 1985. The formation of caliche in soils of the Mojave-Desert, California. Geochimica Et Cosmochimica Acta **49**:57-66.

The problem is that caliche is distributed in patches across the deserts, and larger regional measurements do not exist. Thus, there is a need to better determine where and how much caliche is present across the SoCal deserts (see above discussion).

Inorganic C: Two models that should be used:

HYDRUS 1D

The first step in understanding inorganic C is to determine the equilibrium between pore water gas and water. For this determination, we used sensor readings of temperature, water and CO_2 (Allen et al. 2007). Henry's law states that $[CO_2(aq)]=K_H PCO_2$, where the PCO_2 reading (partial pressure of carbon dioxide, which reflects dissolved C02) is the sensor output converted to atmospheres. The second step is to determine local soil pH (how acidic or basic the soil is) that can be measured directly or determined from $CO_2(aq)$, aqueous carbon dioxide, or the gas dissolved in water, where: $pH = 3.9 - 0.5 \log P_{CO2}$.

Using pH and carbonate equilibrium, we can determine the other species,

$DIC_{total} - [H_2CO_3^*] + [HCO_3^-] + [CO_3^{2-}]$

We can use these sensor data as an input to HYDRUS 1D to simulate the HCO_3 input and output from a known soil layer (Thomas Harmon and Michael Allen, unpublished data).

Allen, M.F., R. Vargas, E. Graham, W Swenson, M. Hamilton, M. Taggart, T.C. Harmon, A Rat'ko, P Rundel, B. Fulkerson, and D. Estrin. 2007. Soil sensor technology: Life within a pixel. BioScience 57: 859-867.

Once the HCO_3^- (bicarbonate) and soil water is known, the soil $C_{inorganic}$ can be determined and converted to the form of caliche ($CaCO_3$) in a known soil layer using the SLIC model (Hirmas et al. 2010).

Expertise: Thomas Harmon, UC Merced; Jirka Simunik, UC Riverside.

Soil Landscape Inorganic Carbon model (SLIC): Hirmas, D.R., C. Amrhein, and R.C. Graham. 2010. Spatial and process-based modeling of soil inorganic carbon storage in an arid piedmont. Geoderma 154:486-494. doi: https://doi.org/10.1016/j.geoderma.2009.05.005

The SLIC model simulates soil $C_{inorganic}$ across the landscape. The strength is that the model simulates the exchanges between carbonate HCO_3^- and $CaCO_3$, caliche. Caliche exists in a solid form when dry. Following water inputs, some of the $CaCO_3$ dissolves into Ca^{2+}, plus CO_2 plus protons. Depending upon the CO_2 concentration (using atmospheric CO_2), plus free Ca, $CaCO_3$ then reforms, the concentration of which depends on the equilibrium chemistry. The fact that dissolution occurs then $CaCO_3$ reforms means that as soil dries out, solid caliche is formed, deeper in the soil profile. As new Ca arrives from erosion, new $CaCO_3$ can form in the soil surface layers. Isotopic data using $\delta^{18}O$, show that there is a continual turnover of the surface layers of $CaCO_3$ when exposed (Allen et al. 2013, confirmed by Mills et al. 2020).

However, a critical missing element is that the SLIC model, as originally developed, is a chemical model only, building upon the soil atmosphere (~400ppm), and does not integrate biological soil respiration, which isotopic ratios have suggested are the source for deep caliche (Schlesinger 1985). $\delta^{18}O$ ratios of surface caliche materials clearly demonstrate continuous turnover in the surface layers, with the potential for loss. Those values, even at 16cm depth, can exceed 2,500ppm. We do not know the CO_2 concentrations deep at the groundwater level.

Hirmas, D.R., C. Amrhein, and R.C. Graham. 2010. Spatial and process-based modeling of soil inorganic carbon storage in an arid piedmont. Geoderma 154:486-494. doi: https://doi.org/10.1016/j.geoderma.2009.05.005

Allen, M. F., G. D. Jenerette, L. S. Santiago. 2013. Carbon Balance in California Deserts: Impacts of Widespread Solar Power Generation*.* California Energy Commission. Publication number: CEC-500-2013-063.

Mills, Jennifer, Laura Lammers, and Ronald Amundson. 2020. Carbon Balance with Renewable Energy: Effects of Solar Installations on Desert Soil Carbon Cycle. California Energy Commission. Publication Number: CEC-500-2020-075

Regional expertise: Daniel Hirmas, Environmental Sciences, UCR

For organic C cycling, an acceptable approach would be to run DayCENT, but integrating the length of C acquisition with access to deep water, extending the time for photosynthesis into each drought period. This requires collection of empirical data of the timing of active photosynthesis coupled with isotopic data on water sources, as per Ogle et al. 2014.

The best models for inorganic carbon would probably be the newest version of Hydrus 1D combined with SLIC, but again integrating empirical data of mycorhizosphere CO2 at the depths where water is acquired and CaCO3 deposited. Together these models coupled with empirical data, particularly for soil CO_2 and the current 3D spatial distributions of Ca, CO_2, and $CaCO_3$, should provide for a solid simulation of desert C and the impacts of anthropogenic and climate stressors on sequestration and fluxes.

(end)