Ecosystem Services and California's Working Landscapes

Market Mechanisms to Revitalize Rural Economies

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A project of the California State Economic Summit's Working Landscapes Action Team and University of California, Agriculture and Natural Resources

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California Economic Summit Action Teams play a key role in developing a roadmap for promoting triple-bottom-line prosperity in California. Working Landscapes is one of seven Action Teams chartered in 2013 to address key priorities that regions across California have identified as critical to creating jobs and promoting competitiveness in through:

- Triple-bottom-line prosperity: simultaneously advancing economic, social and environmental progress.
- Global connectivity: California's competitiveness depends on greater connectivity to global markets.
- Regional alignment: develop a consensus around priorities that are widely shared among regions.

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UC Agriculture and Natural Resources (UC ANR) connects campus-based researchers with offices, programs, and academics in every county to provide science-based information to the people of California through Cooperative Extension and the Agricultural Experiment Stations. Ten Research and Extension Centers host over 1,300 research projects annually. Eleven statewide programs, collaborating with a wide array of external partners, support work on complex issues that need multidisciplinary approaches. UC ANR's mission is to: "Engage UC with the people of California to achieve innovation in fundamental and applied research and education that supports

- sustainable, safe, and nutritious food production and delivery
- economic success in a global economy
- a sustainable, healthy, and productive environment
- science literacy and youth development programs.

Cover images: NRCS, 2011 (all).

I. Executive Summary

California's working landscapes include farmlands, ranches, forests, wetlands, mines, water bodies and other natural resource lands, both private and public. From clean water and nutritious food to climate stability and outdoor recreation, they provide essential benefits for our economy, health and quality of life. But these ecosystem services are often taken for granted, leading to underinvestment in the natural systems that sustain them—a market failure that hits particularly hard in rural areas. A stronger framework for mapping, valuing and investing in ecosystem services can help to protect California's natural capital and narrow the economic divide between its urban and rural regions.

As a step toward such a framework, this report explores current and potential markets for water provision, agricultural production, climate stability, outdoor recreation, and biodiversity. It assesses the prospects for a statewide system to map and model these services across the landscape. And it proposes specific policy measures to build markets, support participation and enhance mapping capabilities, including the following:

- Use Enhanced Infrastructure Financing Districts (EIFDs) or similar mechanisms to create local or regional markets for natural water infrastructure;
- Expand existing markets for farmland and rangeland conservation;
- Expand the market for habitat conservation;
- Expand the market for carbon sequestration;
- Expand and integrate markets for agricultural practices that provide multiple ecosystem services;
- Provide regulatory incentives to support market participation;
- Design programs to be responsive to participants' needs;
- Provide technical assistance to help farmers and ranchers participate in ecosystem services markets; and
- Support mapping technology integration.

By taking these steps, policymakers can forge partnerships with farmers and ranchers, respond to threats such as water scarcity and climate change, and address the growing economic divide between cities that use ecosystem services and rural areas that produce them.

II. Introduction

Ecosystem services are ways that the natural world provides for the well-being of people. They include biological necessities, such as clean water, nutritious food and a livable climate, as well as indirect economic benefits, such as jobs and revenue created along food value chains. More broadly, they encompass intangible goods that contribute to human well-being, such as recreation, aesthetic inspiration and cultural connection. What they have in common is that they depend on "natural capital," or in other words, the generative capabilities of natural systems.[1]

But compared to financial and built capital, natural capital remains undervalued.[2] Many of the services it provides have not been adequately quantified or valued, and those that have are not necessarily linked to the day-to-day economic incentives of farmers, ranchers and other resource managers. The result has been a continuing depletion of natural capital, with examples ranging from falling groundwater levels and loss of productive farmland to poor air quality and declining biodiversity.

In California, however, there is a growing recognition of the importance of natural capital, especially in relation to conserving working landscapes[3] and stabilizing rural economies. The state has become a global leader in linking environmental stewardship and economic development through ecosystem services markets. Its climate policies, for example, integrate resource conservation, infrastructure planning and social equity—and they include programs that protect natural capital by directly paying farmers and ranchers for ecosystem services. While market-based approaches can raise both ethical concerns[4] and practical challenges,[5] they are

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[1] Sen, A., 1985; Nussbaum, M., 2011; Braat, L. and de Groot, R., 2012; Guerry, A. et al., 2015; Schaefer, M. et al., 2015.

[2] See Sukhdev, P., et al., 2010: (discussing a global ecosystem services initiative's conclusion that "failure to incorporate the values of ecosystem services and biodiversity into economic decision making has resulted in the perpetuation of investments and activities that degrade natural capital").

[3] As used here, working landscapes include "farmland, ranches, forests, wetlands, mines, water bodies and other natural resource lands, both private and public." California Forward, 2013.

[4] Jax, K. et al., 2013; Schroter, M. et al., 2014; Silvertown, J., 2015. "Ecosystem services" language has been criticized on the grounds that it reduces the natural world to the benefits it provides for human beings—a single species out of millions—and assigns other life forms a solely instrumental value. See Wuerthner, G., et al., 2014 (exploring arguments against an instrumental, appropriative view of nature). We share these concerns, and believe that the natural world has inherent value beyond the benefits it provides to human beings. But we also recognize that in a market economy, accounting for the economically measurable benefits nature does provide can support management decisions that benefit humans and nature alike.

[5] Daily, G. and Matson, P., 2008. The Cambridge Conservation Initiative (CCI) has found that ecosystem services programs must solve several interrelated problems, including 1) understanding how the flow of useful ecosystem services depends on stocks of natural capital, 2)

showing promising results in California, and have helped to address environmental challenges elsewhere.[6]

In 2012, the California Roundtable on Agriculture and the Environment (CRAE) developed a widely-endorsed set of guidelines for designing ecosystem services programs.[7] The Guidelines for Ecosystem Services Incentive Programs and Policies ("CRAE Guidelines") are reproduced in Table 1. Except where otherwise stated, the policy proposals in this report are intended to be consistent with these guidelines.

Guidelines for Ecosystem Services Incentive Programs and Policies	
1. Eligible Activities	Ecosystem services may be provided both as co-benefits from agricultural activities and from on-farm activities not directly related to the production of food and fiber.
2. Reward Levels	Ecosystem service providers may be compensated for actions that do not necessarily have permanent or long-term impacts, provided that outcomes that garner benefits can be demonstrated. Generally, higher rewards will correspond to longer service provision and greater benefits.
3. Stacking Credits	Practices generating multiple environmental benefits should not be precluded from qualifying for multiple streams of compensation.
4. Minimum Bar	Ecosystem services programs should reward provision of services that are above and beyond an established baseline or regulation and provide mechanisms that recognize early adopters.
5. Value of Transaction	Ecosystem services must have at least one identified buyer or beneficiary to have value, either monetary or other. Ecosystem service programs

quantifying and estimating values for natural capital, 3) incorporating these into policy, 4) creating markets and incentives for resource users to conserve ecological assets, and 5) understanding when investments in ecosystem services can exacerbate the problems they are designed to overcome. CCI, 2015.

[6] See Schmalensee, R. and Stavins, R., 2015 (providing examples of previously implemented market-based approaches to environmental issues in the United States, including the EPA's leaded gasoline phasedown in the 1980's, sulfur dioxide allowance trading in the 1990's, the Regional Clean Air Incentives Market in southern California; NO_x trading in the eastern United States; and the regional Greenhouse Gas Initiative in the northeastern United States).

[7] CRAE, 2012. The CRAE Guidelines are endorsed by a number of agricultural and conservation organizations, including the Agricultural Council of California, American Farmland Trust, California Association of Resource Conservation Districts, California Association of Winegrape Growers, California Farm Bureau Federation, California Grape and Tree Fruit League, California Rice Commission, Community Alliance with Family Farmers, Defenders of Wildlife, Environmental Defense Fund, King and Gardiner Farms, Markon Cooperative, California Chapter of The Nature Conservancy, Roots of Change, Sustainable Conservation, San Joaquin Resource Conservation District and Western United Dairymen.

	should link beneficiaries to producers individually or in pooled or aggregated groups that minimize risk.
6. Tailored Local Approach	Different benefits in different locations deserve tailored approaches rather than a one-size-fits-all framework. Connect site-level efforts with landscape- or regional-scale conservation strategies.
7. Scientific Basis	Credits should be supported by science to allow quantification with appropriate and current metrics and achieve a balance between accuracy and practicality.
8. Oversight	Where appropriate, there should be rules established and governed by a neutral third party. Monitoring, reporting, and verification systems, as well as a methodology for maintaining an inventory, must be developed as integral components of an ecosystem services program. These systems should strive to ensure environmental outcomes while balancing precision with costs of implementation.
9. Regulatory Alignment	Programs must not create additional burden or transaction costs through conflict with other regulatory requirements. Furthermore, relevant regulatory entities should be engaged in developing the program in order to anticipate and overcome barriers upfront.

Table 1: CRAE Guidelines for Ecosystem Services Incentive Programs and Policies (CRAE, 2012).

More broadly, the guidelines are intended to create incentives to conserve and steward California's irreplaceable working landscapes. If successfully implemented, integrated ecosystem service programs can help California to address pressing challenges like farmland conversion, water scarcity and climate change, while also bringing much-needed economic growth to rural communities.

III. Classifying and Bundling Ecosystem Services

Each ecosystem service has a different relationship to the natural capital that sustains it, to other services, and to the financial economy. Moreover, many services are integrally linked, and cannot be decoupled without impairing each other. Timber harvesting or crop cultivation on steep hillsides, for example, can accelerate soil erosion, diminishing services such as nutrient cycling, flood control and aesthetic value.

A widely accepted framework for understanding these relationships and identifying "bundles" of ecosystem services was developed by the United Nations in the Millennium Ecosystem Assessment (MA).[8] At the heart of this framework are four categories of ecosystem services:

[8] MA, 2005; ICSU-UNESCO-UNU, 2008. Building on the MA framework, international institutions, federal and state agencies, universities, corporations and nonprofits have begun developing policies and programs to assess and value ecosystem services. Nunes, P. et al., 2014;

- **Provisioning services** offer a specific, tangible resource, such as water, food or fiber.[9] These services are the easiest to monetize, and many are already delivered by private businesses, but the natural capital that supports them is still vulnerable to underinvestment. For example, California publishes annual statistics on crop production, and a number of studies have attempted to quantify the broader agricultural value chain, but economic incentives for individual farmers often favor the sale of natural capital (farmland) to developers.
- **Regulating services,** such as climate stability, water treatment and pest control, keep the biosphere livable for people.[10] These benefits are just as important as provisioning services but more difficult to monetize without government regulation and public investments. Climate stability, for example, depends in part on the capacity of the atmosphere to regulate temperature, but this natural capital has been severely depleted by GHG emissions from the burning of fossil fuels. California and other governments have established cap-and-trade programs, which offer permits for specified quantities of GHG emissions. These programs use market mechanisms—putting a price on carbon and other pollutants—to create economic incentives to protect the atmospheric commons, and invest the proceeds in mitigation strategies.
- **Cultural services** include intangible benefits such as natural beauty, aesthetic inspiration and overall well-being, as well as more easily monetized services such as recreation.[11] Some can be quantified indirectly (for example, through measures of spending on outdoor recreation) but others are incommensurable with economic valuations.
- **Supporting services**, such as nutrient cycling and soil formation, are ecological processes or conditions that make the other services possible.[12] These services are difficult to monetize because they occur over long periods of time and involve complex interrelationships. The economic value of biodiversity, for example, is unclear in the abstract, but ecosystems composed of only a few species tend to be less resilient and less productive over time. These depleted systems provide fewer supporting services, and are less capable of sustaining the provisioning, regulating and cultural services on which we

Schaefer, M., et al., 2015. International examples include the United Nations Statistical Commission of the System for Environmental-Economic Accounts (SEEA) and the World Bank sponsored Wealth Accounting and Valuation of Ecosystem Services (WAVES). UNSC, 2012; TWB, 2016. In the United States, the President's Council of Advisors on Science and Technology (PCAST) and the Council on Environmental Quality (CEQ) sought to incorporate natural capital and ecosystem services into federal policy during the Obama Administration. PCAST, 2011; EOP, 2013. In California, the MA framework was used to organize a study of ecosystem services in Santa Clara County. Batker et al., 2014.

[9] MA, 2005; ICSU-UNESCO-UNU, 2008.
[10] MA, 2005; ICSU-UNESCO-UNU, 2008.
[11] MA, 2005; ICSU-UNESCO-UNU, 2008.
[12] MA, 2005; ICSU-UNESCO-UNU, 2008.

depend. Thus, even if we cannot put a price on a specific increment of biodiversity (for example the difference between a forest with *n* species and a forest with *n-1* species), there is a compelling practical and economic rationale for conserving this type of natural capital.

Table 2 provides a more detailed list of the types of services in each category, while Figure 1 illustrates the association and strength of each category's connection to human well-being.

Ecosystem Goods and Services	
Good or Service	Economic Benefit to People
Provisioning Services	
Food	Producing crops, fish, game, and fruits
Medicinal Resources	Providing traditional medicines, pharmaceuticals, and assay organisms
Ornamental Resources	Providing resources for clothing, jewelry, handicrafts, worship, and decoration
Energy and Raw Materials	Providing fuel, fiber, fertilizer, minerals, and energy
Water Supply	Provisioning of surface and groundwater for drinking, irrigation, and industrial use
Regulating Services	
Biological Control	Providing pest and disease control
Climate Stability	Supporting a stable climate through carbon sequestration and other processes
Air Quality	Providing clean, breathable air
Moderation of Extreme Events	Preventing and mitigating natural events such as floods, hurricanes, fires, and droughts
Pollination	Pollination of wild and domestic plant species
Soil Formation	Creating soils for agricultural and ecosystems integrity; maintenance of soil fertility
Soil Retention	Retaining arable land, slope stability, and coastal integrity
Water Treatment	Improving water quality by decomposing human and animal waste and removing pollutants
Water Regulation	Providing natural irrigation, drainage, groundwater recharge, river flows, and navigation
Supporting Services	
Habitat and Nursery	Maintaining genetic and biological diversity, the basis for most other ecosystem functions; promoting growth of commercially harvested species
Genetic Resources	Improving crop and livestock resistance to pathogens and pests
Cultural Services	
Natural Beauty	Enjoying and appreciating the presence, scenery, sounds, and smells of nature
Cultural, Historical and Artistic Inspiration	Using nature as motifs in art, film, folklore, books, cultural symbols, architecture, and media
Recreation and Tourism	Experiencing the natural world and enjoying outdoor activities
Spirituality	Harboring in nature for religious and spiritual purposes

Table 2: Categories of ecosystem goods and services (adapted from de Groot, R. et al., 2002; Sukhdev, P. et al., 2010; Batker, E. et al., 2014).

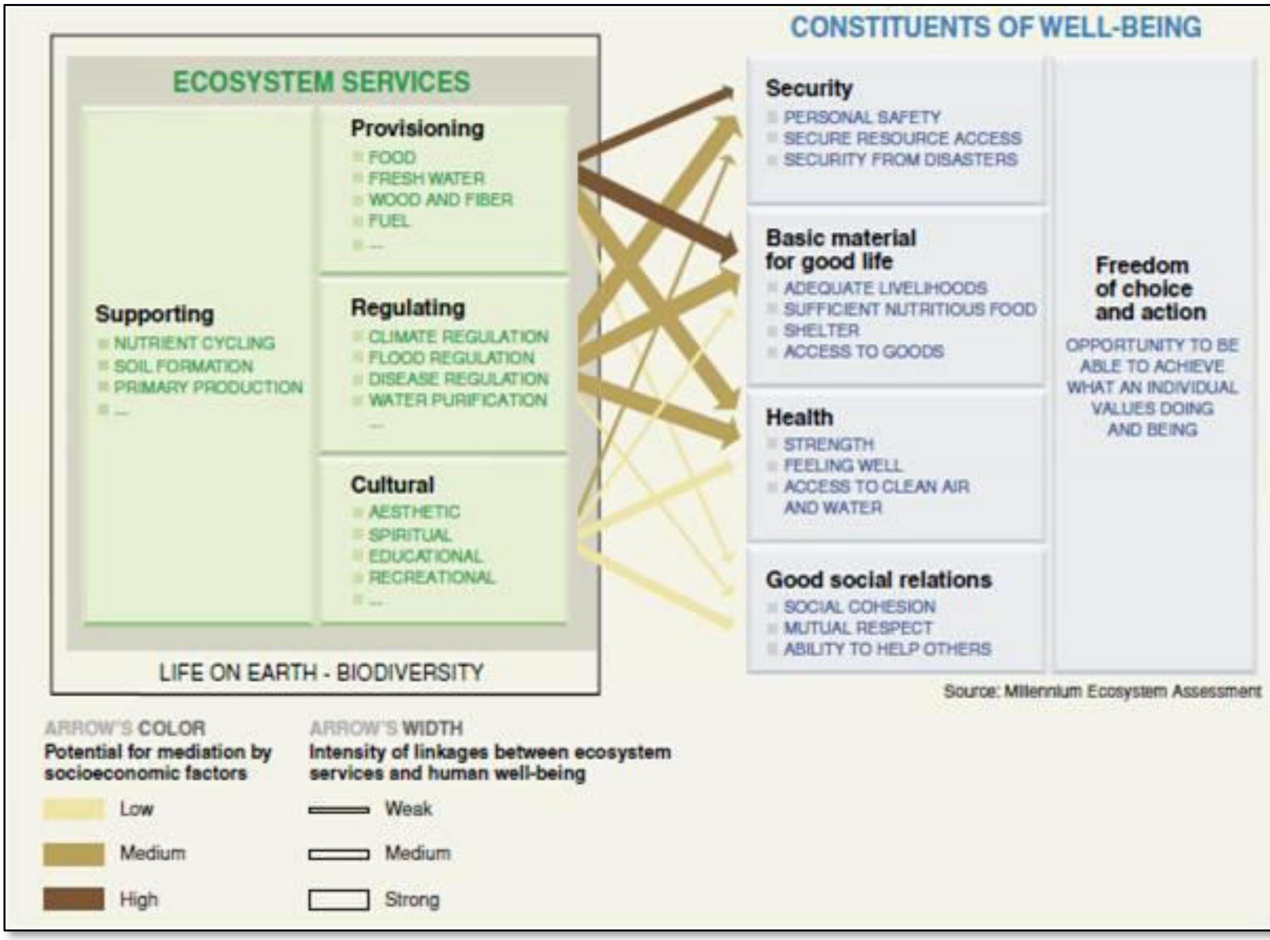

Figure 1: Ecosystem service linkages and returns (reproduced from MA, 2005).

The MA's categories suggest avenues to map, measure and account for multiple benefits in particular landscapes or regions.[13] Scenarios involving these bundles of services can help to conceptualize the complex tradeoffs and returns involved in landscape-level natural resource management.[14] The "multiple services" box in Figure 2, for example, illustrates where provisioning, regulating and cultural services, and the supporting services of biodiversity, are maximized under different types of land use. This box also represents the stacking of credits (and increased payments for services) referenced in the CRAE guidelines.

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[13] Chan, K., et al., 2006; Egoh, B., et al., 2008; Nelson, E., et al., 2009.
[14] Rodriguez, J., et al. 2006; Kareiva, P., et al., 2007; Raudsepp-Hearne, C., et al., 2010.

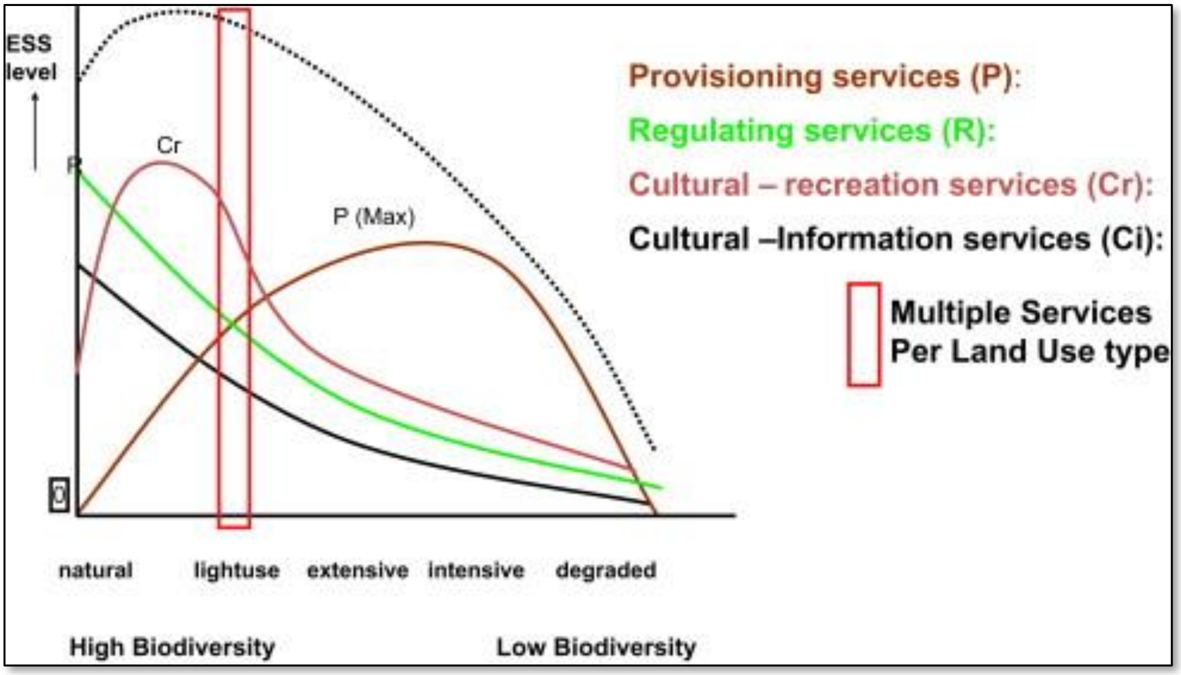

Figure 2: Bundling multiple ecosystem services per land use (reproduced from MA, 2005).

Building on the foundation of the MA categories, this report considers existing and potential markets for five ecosystem services:

- The provisioning services of **water supply** and **agricultural productivity**;
- The regulating service of **climate stability**;
- The cultural service of **recreation and tourism;** and
- The supporting service of **biodiversity**.[15]

These services are interrelated and connected with others not included in this paper. For example, groundwater recharge areas that contribute to water supply often overlap with riparian habitat (biodiversity) and prime farmland (agricultural production). Similarly, the forests, wetlands and other working landscapes that collect and channel water can also remove heavy metals, nitrates and other toxins from it,[16] thereby contributing to the regulating service of water treatment.[17] Taken together, these five ecosystem services offer an entry point to understanding the opportunities and difficulties of creating markets to protect and utilize natural capital for human well-being.

[15] Batker, D., et al., 2014.
[16] Nowak, D., 2007; Duffy, W. and Kahara, S., 2011.
[17] Water treatment is not discussed in detail below, but in many cases, it is supported by the same natural capital that contributes to water supply.

IV. Ecosystem Services on Working Landscapes

A. Water Supply (Provisioning Services)

Water is a physical necessity for life, and a central organizer of ecosystems and landscapes.[18] Most California water begins as precipitation or snowpack in high elevation areas, which is then transported by rivers, reservoirs, and built infrastructure to downstream users.[19] While much of the surface water supply falls as rain or snow in the winter, the greatest demand occurs in the summer. Ecosystem services that support water provision—the collection, storage and release of water in forms useful to people, agriculture and the environment—are therefore essential.

Water supply services are provided in part by man-made infrastructure, such as dams, reservoirs and canals, but can often be obtained more cost-effectively using natural capital, such as functioning watersheds and sustainably managed aquifers.[20] Healthy forests in upper watershed areas, working in concert with riparian corridors, wetlands and groundwater recharge areas downstream, can help secure long-term supplies of clean drinking water.[21] In New York City, for example, the U.S. Environmental Protection Agency, the state's Department of Environmental Conservation and environmental organizations have partnered to integrate natural capital—1,900 square miles of the Catskill and Delaware Watersheds in upper New York State—into one of the largest engineered water systems in the United States. Natural systems now supply and filter more than a billion gallons of water a day for approximately nine million New Yorkers. Moreover, both urban and rural residents benefit from an agreement that includes land acquisition, conservation easements, comprehensive planning, and implementation of best management practices for farmland, riparian areas and forests.[22]

There are opportunities to replicate this success. In California, voters have authorized major investments in water infrastructure, and the state's Legislature has explicitly recognized source watersheds as part of this infrastructure. The Water Quality, Supply, and Infrastructure Improvement Act of 2014 (Proposition 1) authorizes $7.545 billion in bonds for water projects, including surface and groundwater storage, ecosystem and watershed protection, and drinking water programs.[23] And AB 2480, passed in 2016, explicitly declares that "source watersheds are

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[18] Sedell, J. et al., 2000.
[19] Many of these areas are managed by public agencies such as the National Park Service and National Forest Service.
[20] American Rivers, et al., 2012. Natural water infrastructure can provide regulating services as well, including stormwater management, flood control and water treatment.
[21] Vose, J., et al., 2012; Creed, I., et al., 2014.
[22] RAND, 2016. See NYC, 2016: This system is significantly cheaper than the $8-10 billion it would have cost to construct artificial filtration systems and the $1 million per day it would cost to operate them.
[23] California State Water Resources Control Board, 2017.

recognized and defined as integral components of California's water infrastructure." As a result, restoration and conservation of source watersheds is eligible for the same financing as other water collection and treatment infrastructure.[24]

An ecosystem services market for water supply, however, must be carefully designed to fill gaps in investment while taking into account the complexities of water law and pricing. California has multiple water rights regimes, various markets for buying and selling water rights, and different price structures for urban and agricultural end users.[25] While most end users do pay for access to water, investment in natural capital, such as functioning watersheds and sustainably managed aquifers, is uneven at best. Some federal programs fund conservation and land management practices that support watershed function, including the Environmental Quality Incentives Program (EQIP), Conservation Stewardship Program (CSP), Agricultural Conservation Easement Program (ACEP), Healthy Forests Reserve Program (HFRP), Conservation Reserve Program (CRP) and Conservation Reserve Enhancement Program (CREP).[26] In California, irrigation districts have begun paying farmers to flood orchards instead of draining them, and researchers at U.C. Davis are exploring which soil conditions and crop species are most conducive to flooding.[27] Applying an ecosystem services framework to these programs could foster a stronger focus on natural capital that supports water provision.[28]

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[24] California Legislative Information, 2017.

[25] For urban users, costs depend in part on residential or commercial status, metering (or lack thereof), and utility conservation incentives. For agricultural users, costs depend on the source of the water—for example, water imported through the State Water Project or Central Valley Project, water from a local ditch company or groundwater extracted on the farmer's own property—and other factors.

[26] See Wainger, L., et al., 2017 (listing these programs and using a case study to quantify and value their water-related benefits).

[27] Corbett, J. (personal communication, September 25, 2017). See also O'Geen et al., 2015 (incorporating multiple factors, including the ability of soils to transmit water beyond the root zone and the saturation tolerance of different crops, into a "Soil Agricultural Groundwater Banking Index").

[28] Such a framework could draw on guidelines issued by the Executive Office of the President's Council on Environmental Quality (CEQ) in 2013. This set of policies used an ecosystem services approach to capture the interconnected economic, environmental and social effects associated with federal investments in water resources. Water resource evaluations were suggested for a range of services, including water quality, nutrient regulation, flood and drought mitigation, water supply, aquatic and riparian habitat, biodiversity, carbon storage, agricultural production, raw materials, transportation, public safety, power generation, recreation, educational and cultural values. Under the CEQ framework, these services are to be "measured monetarily and non-monetarily, and include quantified and non-quantified effects. Existing techniques, including traditional cost-benefit analyses, are capable of valuing a subset of the full range of services, and over time, as new methods are developed, it is expected that a more robust ecosystem services based evaluation framework will emerge." Natural infrastructure is highlighted within the federal guidelines as a means to "generally avoid or minimize adverse

Recently, the Sustainable Groundwater Management Act (SGMA) created a framework for local groundwater regulation, which will affect management of natural capital that provides water in California. SGMA implementation is just beginning, but bringing groundwater use in line with supply may raise the price of water, while providing incentives for conservation and investment in groundwater recharge areas.

B. Agricultural Production (Provisioning Services)

California's agricultural industry is unparalleled in its productive capacity and significantly contributes to ensuring national food security. Its farmland and rangeland, mapped in Figure 3, produce over 400 different commodities and were responsible for more than $47 billion in crop receipts in 2015.[29] The state ranks number one in the production of fruits, tree nuts and berries, with 41.4% of national sales.[30] Among other crops, California produces almost all of the almonds, artichokes, dates, figs, raisins, kiwifruit, olives, pistachios, pomegranates, sweet rice and walnuts grown in the United States.[31]

changes" while also being "the most cost effective and environmentally protective alternative to implement." CEQ, 2013.

[29] CDFA, 2016.

[30] USDA, 2012.

[31] Tolomeo, V., 2015; CDFA, 2016.

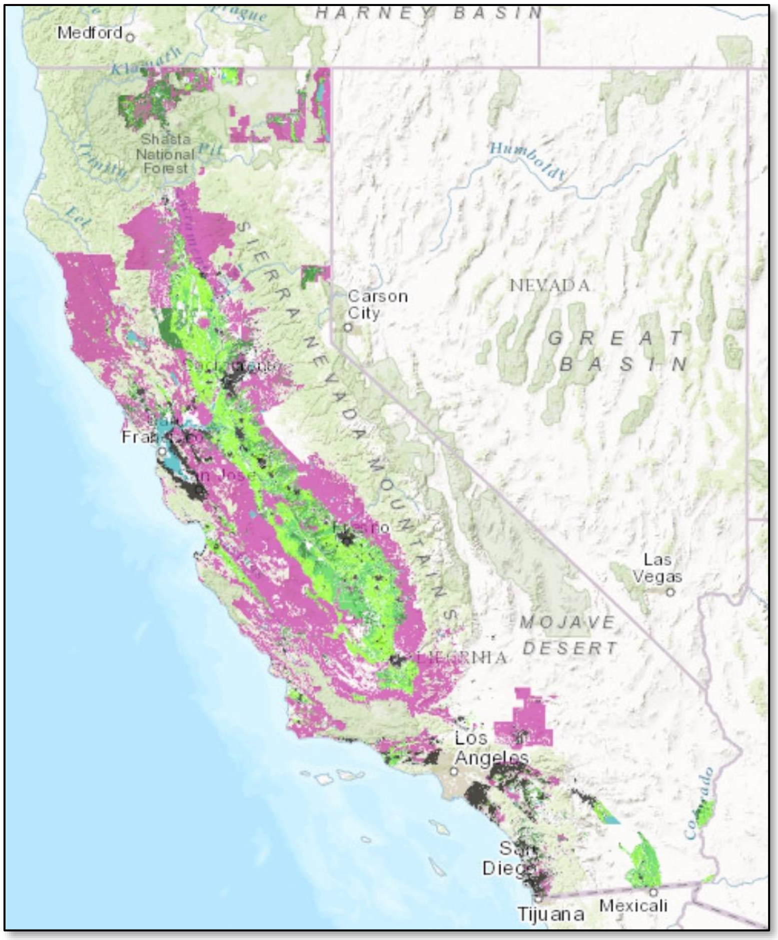

Figure 3: Prime Farmland, farmland of statewide importance, unique farmland and farmland of local importance (scaled from light to dark green in that order), grazing land (purple) and developed land (black) in California (DOC, 2014).

Beyond farm gate sales, a 2011 study found that California's agricultural value chain supports upwards of 2.5 million jobs in over 800 employment categories at an average salary of $50,000, and that it contributes over $300 billion a year to the state's economy.[32] Another study found that for every $1 billion in farm sales, 18,000 jobs are created: 11,000 growing food, and 7,000 in other sectors such as processing and distribution.[33] Taking these contributions into account, the University of California's Agricultural Issues Center found a combined multiplier effect of $2.27, meaning that for every dollar of farm gate sales, another $1.27 was added to the state's economy.[34] In short, agricultural production is a critical component of California's economy.

But between 1982 and 2012, 1,842,000 acres of farmland and rangeland were consumed by development.[35] California's agricultural land—one of the foundations of its economy—continues

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[32] COE, 2011.
[33] UC AIC, 2009
[34] UC AIC, 2009.
[35] Farmland Information Center, 2017.

to be threatened by urbanization, climate change and other environmental and economic factors that require mitigation.[36] Ecosystem services analyses can quantify the long term costs that are sometimes masked by short term opportunities, such as suburban sprawl.[37]

Farmland conservation can help to avert these costs, while providing additional benefits for the built environment,[38] air quality,[39] public health,[40] property values,[41] and tax revenues.[42] For example, studies on the cost of community services have linked farmland and open space protection with the fiscal stability of cities.[43] Infill development—a corollary of land conservation in a state where the population is increasing—provides additional benefits, including higher tax revenue per acre, reduced service and infrastructure costs, diversified economic activity, job creation, increased walkability, and reduced transportation costs.[44]

Federal and state programs are already available to help farmers, ranchers and others realize these benefits. Natural Resource Conservation Service (NRCS) programs,[45] as well as the California Farmland Conservation Program[46] and local farmland mitigation programs, provide funding for conservation easements.[47] The Williamson Act, meanwhile, creates a market for

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[36] Pitesky, M., et al., 2014.
[37] Kroeger, T., 2008.
[38] Ewing, D., et al., 2002.
[39] Niemeier, D., et al. 2011.
[40] Dannenberg, A., et al., 2003; McCann, B. and Ewing, R., 2003.
[41] Kroeger, T., 2008.
[42] Infill Builders Association, et al., 2012.
[43] AFT, 1986; .AFT, 1992; AFT, 1993; RERC, 1974; Ewing, R., 1994; Muro, M. and Puentes, R., 2004; Thorne, J., et al. 2006; Beardsley, K., et al., 2009; Kotchen, M. and Schulte, S., 2009; Litman, T., 2016.
[44] Burchell, R., et al., 2005; US EPA, 2012.
[45] See Wainger, L. and Irvin, D., 2017 (collecting studies of ecosystem services benefits provided by USDA programs).
[46] DOC, 2017a.
[47] At the state level, another example is the mitigation requirements associated with high speed rail. In some cases, counties, cities and transportation agencies have similar requirements. See, e.g., San Joaquin County Ordinance Code §§ 9-1080.1 *et seq*. (county-level mitigation program); Yolo County Zoning Code § 8-2.404 (county-level mitigation program); City of Davis Municipal Code §§ 40A.03.010 *et seq*. (city-level mitigation program); see also Greater Salinas Area Memorandum of Understanding (2006 agreement between the County of Monterey and City of Salinas to acquire agricultural conservation easements "in the unincorporated areas to the west and south of [Salinas'] Sphere of Influence" in order to direct new development to less agriculturally productive land north and east of Salinas).

temporary agricultural conservation by offering landowners a lower property tax rate for a ten- to twenty-year term in exchange for keeping their land in agriculture.[48]

Complementing farmland conservation programs, the Environmental Quality Incentives Program (EQIP), Conservation Stewardship Program (CSP) and Wildlife Habitat Incentives Program (WHIP) create markets for the sustainable stewardship of agricultural land. Once funded, California's Healthy Soils Program (discussed in more detail below) is designed to take a similar approach by investing in agricultural practices that support carbon sequestration.

In recent years, the climate crisis has prompted an alternative accounting of ecosystem services associated with farmland. Studies have found that per-acre greenhouse gas emissions from irrigated cropland are up to 70 times lower than those from urbanized areas.[49] In Yolo County, for example, urban areas account for 86 percent of greenhouse gas emissions while unincorporated, primarily agricultural areas are responsible for the remaining 14 percent.[50] Moreover, a growing body of research indicates that alternative agricultural management practices, such as winter cover cropping and avoidance of overfertilization, can further reduce GHG emissions.[51] Local farmland conservation efforts—especially adjacent to urban areas—are increasingly viewed as climate mitigation strategies and approaches to stabilizing pollution.

The Sustainable Agricultural Lands Conservation Program (SALCP) is one of the newest conduits for public investment in farmland conservation. This precedent-setting program brings revenue generated through the state's cap-and-trade program (discussed in more detail below) to farms and ranches in rural California.[52] It primarily funds agricultural conservation easement acquisitions, though it also supports planning and policy development. With adequate funding levels, SALCP could play a significant role in conserving the natural capital that supports the rural agricultural economy.

In many cases, however, the markets created by farmland protection and stewardship programs are insufficiently funded and lack widespread buy-in from farmers and ranchers.[53] Without well-

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[48] Implementation of the Williamson Act has been hampered by the state's failure to provide subvention payments to counties. Without these payments, Williamson Act contracts effectively shrink the local tax base, giving counties an economic incentive not to support them.
[49] Haden, V., et al., 2012; Jackson, L., et al., 2012.
[50] Yolo County, 2010.
[51] De Gryze, S., et al., 2009.
[52] In addition, at least 25% of cap-and-trade proceeds must benefit disadvantaged communities, many of which are in rural regions. DOC, 2016.
[53] For ranchers in particular, conservation practices that generate public benefits have not been profitable enough to adopt, either because they are too costly to implement or because the benefits accrue mainly to the public rather than the landowner. Kroeger, et al., 2010. Beyond publicly subsidized programs, there are currently no established markets that allow ranchers to

funded conservation efforts or strong political commitments reflected in land use policy (such as urban growth boundaries), farms and ranches in proximity to urban development will continue to be subject to speculation by developers and underinvestment by landowners waiting to sell.

C. Climate Stability (Regulating Services)

California's economy depends on a stable climate. Irrigated agriculture, in particular, is acutely sensitive to climate change. Water systems are premised upon reliable annual precipitation, and many crops have specific sensitivities to temperature variation. Transportation infrastructure such as inland highways, railways and bridges also functions reliably only within certain temperature parameters,[54] while coastal cities and ports are vulnerable to sea level rise.

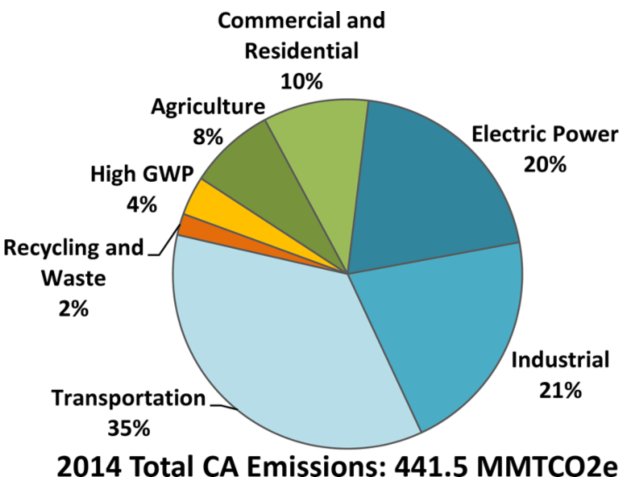

Figure 4: California Greenhouse Gas Emissions by Scoping Plan Category (reproduced from CARB, 2016c).

But the environment's ability to act as a sink for carbon dioxide (CO_2) and other heat-trapping pollutants is being overwhelmed. Driven by emissions from fossil fuel consumption, atmospheric CO_2 levels have risen to over 390 parts per million, or 39% above preindustrial levels.[55] Without additional efforts to stabilize and reduce GHG emissions, average global temperatures are expected to increase by anywhere from 2.5° to 7.8° Celsius by 2100.[56] A 1.5° increase—the target of voluntary emissions pledges made under the 2015 Paris Agreement—is expected to lead to extreme weather events, significant impacts on agriculture and other changes "at the upper limit of present-day natural variability."[57] An increase of 2° or higher would mark "a new climate regime" with substantial danger for agriculture, coastal communities and other elements of human civilization.[58]

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be compensated for the services they provide. In addition, skepticism of climate change and distrust of government have been deterrents to participation in some of these programs. Realizing fuller participation may require more detailed cost/benefit analysis of specific practices, stronger economic incentives to spur partnerships, and more sophisticated approaches to connecting ecosystem services with demand. Cheatum, et al., 2011a: 3. InVEST may be a useful tool for developing these approaches. Kroeger, T., et al., 2010.

[54] SACOG and CivicSpark, 2015.
[55] IPCC, 2012; IPCC, 2007.
[56] IPCC, 2014.
[57] Schleussner et al., 2016.
[58] Schleussner et al., 2016.

As the natural capital that sustains climate stability has been rapidly depleted, California has responded with an array of climate policies and investments, including a market-based approach to reducing GHG emissions. The Global Warming Solutions Act (AB 32) of 2006, Sustainable Communities and Climate Protection Act of 2008 (SB 375) and recently-passed SB 32 created a series of policies and programs to reduce California's greenhouse gas emissions to 40 percent below 1990 levels by 2030. This overall framework, which is still developing as regulations and program guidelines are formulated, has broad implications for future economic development and sustainability goals in the state.

Under AB 32, the California Air Resources Board developed an initial Scoping Plan in 2008, and updates it every five years. The plan impacts all sectors of the economy and introduces multiple approaches to achieve compliance, including market approaches, planning policies, incentives, direct regulations and voluntary efforts.[59] Scoping Plan categories, illustrated in Figure 4, identify greenhouse gas emissions percentages by economic sectors.

A price for carbon is determined by allowance trading under a cap-and-trade program.[60] These programs "cap" greenhouse gas emissions each year for covered facilities. The cap represents the overall target of allowed emissions from all included facilities. Covered entities can sell off or "trade" allowances (rights to emit) they do not need. Each allowance is a tradable permit for the emission of one metric ton of CO_2 with the sum of all allowances equivalent to the overall emissions cap. Revenue proceeds from allowance auctions must be used to mitigate greenhouse gases or their harmful effects.[61]

Proceeds from cap-and-trade auctions are placed in the Greenhouse Gas Reduction Fund and are appropriated through a two-step process with state agencies drafting three-year investment plans with priorities for auction proceeds. Priorities are incorporated into policy by both the Legislature and Governor through the state's annual budget process. Recent executive orders and laws require that state agencies address climate impacts through natural infrastructure, as opposed to additional built infrastructure, wherever possible (EO B-30-15), mandate climate adaption and resiliency coordination through the Governor's Office of Planning and Research (SB 246), and require local governments to identify the risks of climate change (SB 379).

Market based approaches like California's cap-and-trade program incentivize innovations and encourage firms to reduce emissions at a cost lower than the allowance price, thereby reducing the cost of compliance and need to purchase more allowances. Today, across the globe, cap-and-trade programs continue to be implemented in the European Union, Switzerland, Australia, New

[59] CARB, 2016a.
[60] CARB, 2016b.
[61] C2ES, 2011; CPI, 2016.

Zealand, several Canadian provinces, Japan and several Chinese cities and provinces.[62] In North America, the Western Climate Initiative began in 2007 consisting of a voluntary coalition of US states and Canadian provinces,[63] and recently California's and Quebec's cap-and-trade programs have been linked.[64]

California promises to be a proving ground of climate policy development and implementation over the coming decade. Its policies align investments in multiple ecosystem services with associated co-benefits such as infill development, water system sustainability, and natural and working lands stewardship.[65] Working landscapes, in particular, will be instrumental in achieving these goals, as per-acre emissions from California's farms are an average of 58 times lower than those from its urban areas,[66] per-acre emissions from rangeland may be up to 217 times lower,[67] and natural landscapes such as oak woodlands have been shown to sequester millions of tons of carbon.[68] As noted above, SALCP funds conservation of agricultural lands, the Healthy Soils Program has the potential to fund management practices that sequester carbon, and other climate programs support land use and transportation planning directed at lowering GHG emissions by reducing dependence on driving.[69]

D. Recreation and Tourism (Cultural Services)

Many of the cultural services provided by working landscapes are difficult to price, but outdoor recreation has substantial and measurable economic impacts. These services ground the sometimes esoteric idea of ecosystem services in quantifiable ways that regular people experience and understand.

The economic significance of outdoor recreation is particularly evident on public lands. As illustrated in Table 3, visits to parks managed by the National Park Service (NPS) supported $32 billion ($33.5 billion in 2017 dollars) in economic output and contributed more than 295,000

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[62] Ranson, M. and Stavins, R., 2013.
[63] WCI, 2016.
[64] Kroft, P. and Drance, J. 2015.
[65] California Energy Commission, 2016.
[66] Shaffer, S. and Thompson, E., 2015.
[67] Jackson, L., et al., 2012.
[68] Gaman, T., and Firman, J., 2006; Gaman, T., 2008.
[69] While not creating a direct market for natural capital that supports climate stability, the incorporation of climate concerns into land use and transportation planning can provide opportunities to conserve working landscapes on a regional scale. See Livingston, A., 2016: (examining current and potential policies to support conservation in Sustainable Communities Strategies around the state).

jobs to the economy in 2015.[70] In California alone, NPS visits supported over $2.5 billion in economic output and nearly 26,000 jobs. U.S. Forest Service lands in California were responsible for another $1.1 billion in visitor spending, more than 10,000 jobs and $461.5 million in labor income.[71]

National Park Service Visitor Spending Effects (Nationwide, in 2015 dollars)	
Total Recreational Visits	307,200,000
Total Visitor Spending	$16,900,000,000
Jobs	295,000
Labor Income	$11,100,000,000
Value Added	$18,400,000,000
Economic Output	$32,000,000,000
National Park Service Visitor Spending Effects (California, in 2015 dollars)	
Total Recreational Visits	38,366,828
Total Visitor Spending	$1,774,000,000
Jobs	25,771
Labor Income	$1,004,900,000
Value Added	$1,546,700,000
Economic Output	$2,562,700,000

Table 3: National Park Service visitor spending effects in the U.S. as a whole (top) and California (bottom) (adapted from Cullinane and Koontz, 2016 and NPS, 2016).

State and regional parks offer further evidence of the economic benefits of outdoor recreation. In 2014, the California State Park System brought in over $103 million in visitor fees, and employed nearly 1,500 full-time workers.[72] Though state parks are publicly subsidized, they provide a significant benefit to the state's economy. A 2010 California State Parks Foundation report, illustrated in Table 4, found that the total economic impact of state park visits, including not only visitor fees but also lodging, food, transportation, outdoor recreation equipment and other expenditures, was approximately $6.8 billion ($7.69 billion in 2017 dollars), and that it supported 56,000 jobs in multiple sectors of the economy.[73] Taking tax revenue into account, the study found that this economic activity "return[s] over two dollars to the State treasury for each

[70] Cullinane T. and Koontz, L., 2016. Economic output includes the total estimated value of the production of goods and services supported by NPS visitor spending, and is the sum of all intermediate (business to business) and final (sales to customers) sales.
[71] Stroud, D. and Reckler, S. (personal communications, October 3, 2017).
[72] California State Parks System, 2015.
[73] California State Parks Foundation, 2010.

dollar spent on operating and maintaining the [State Park System]." [74] And local and regional parks make an even greater contribution, as shown in Table 5.[75]

California State Parks – Economic Benefits for 2010 (in 2010 dollars)	
Total Recreational Visits	65, 500,000
Total Visitor Spending Related to Park Visits	$3,200,000,000
Average Daily Visitor Spending	$42 per day
Jobs	56,000
Total Labor Income	$2,300,000,000
State Tax Revenue	$289,000,000
Local Tax Revenue	$145,000,000
Total Economic Impact	$6,810,000,000

Table 4: Economic impact of California State Parks (adapted from California State Parks Foundation, 2010).

Local and Regional Parks – Economic Benefits (Nationwide)	
Jobs	990,000
Labor Income	$43,790,181,000
Value Added (GDP)	$67,951,541,000
Total Economic Output	$139,628,226,000
Local and Regional Parks – Economic Benefits (California)	
Jobs	126,775
Labor Income	$7,269,695775
Total Economic Output	$17,612,301,914

Table 5: Economic output from local and regional parks in the U.S. as a whole (top) and California (bottom) (adapted from Center for Regional Analysis, 2015).

Federal lands, California State Parks and local park systems illustrate the economic output, business opportunities and job creation spurred by public stewardship of culturally and ecologically important places. Even beyond these benefits, proximity to natural areas has been shown to increase property values for homeowners and businesses, which not only benefits them individually, but generates more tax revenue for local governments.[76]

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[74] California State Parks Foundation, 2010.
[75] Center for Regional Analysis, 2015.
[76] Crompton, J., 2001; Crompton, J., 2005; Coleman, W., 2017. See Active Living Research, 2010 (finding that this effect is particularly evident when access to open space is combined with other public health and quality of life benefits, such as walkable neighborhoods).

But not all outdoor recreation occurs on public land. Many farms and ranches are also agritourism sites, hosting attractions such as farm stands, U-pick, farm stays, tours, on-farm classes, festivals, pumpkin patches and corn mazes, Christmas tree farms, weddings, dinners, youth camps, barn dances, hunting or fishing, and guest ranches.[77] World Wide Opportunities on Organic Farms (WWOOF), for example, has developed its own unique global economy, network and culture. It is an informal international network of linked national organizations that coordinate farm stays on organic farms. Participants are volunteers who are not paid but are instead compensated with food, lodging, educational opportunities and the experience of rural life. In return, farmers receive labor assistance with their farming operations.

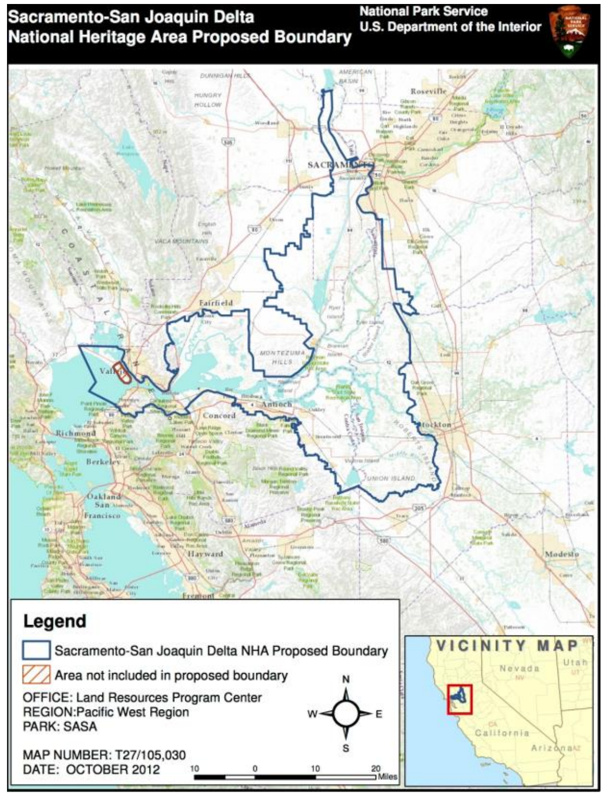

Figure 5: Sacramento-San Joaquin Delta National Heritage Area Proposed Boundary (reproduced from Weiser, M. 2017).

Fostering recreational markets for working landscapes is difficult. Many landowners associate these activities with allowing public access to their properties. While these opportunities work for particular farms and ranches, how can "parks" be conceptualized on a landscape level?

An underutilized approach to landscape level conservation and recreation on working landscapes—and one that does not impeded productive business enterprise—is the National Heritage Area. These flexible, "lived-in landscapes" value historic, cultural and natural resources with economic development combined within a comprehensive framework under the National Park Service. First initiated in 1984 by President Reagan, who described them as "a new kind of national park," there are now 49 across the country.[78] In California, the proposed Sacramento-San Joaquin Delta National Heritage Area, illustrated in Figure 5, emphasizes the area's national significance as an inland delta, its multicultural heritage, its agricultural productivity, and its place at the heart of California's complex water infrastructure.[79] While there are fewer markets for conservation of traditional "parks," National Heritage Areas and other innovative approaches may create frameworks to integrate protection of historic, cultural and natural resources with economic development.

[77] UCCE, 2017.
[78] NPS, 2017.
[79] Delta Protection Commission, 2012.

E. Habitat Biodiversity (Supporting Services)

Biodiversity represents and involves the supporting services upon which the ecosystem functions, including processes of primary production, nutrient cycling and soil formation.[80] These services provide the basis for all other provisioning, regulating and cultural services—the MA categories used in this report to reference and conceptualize ecosystem services.

Tradeoffs become apparent within the ecosystem services framework when considering the supporting service of biodiversity. In particular, not all ecosystem services can be valued in the same way, and these foundational natural capital assets can be difficult to quantify. Moreover, as ecosystems are impaired, these services diminish or cease to function at all. For example, without ongoing nutrient cycling and soil formation—which depend on ecological actors ranging from bacteria to livestock—even the best farmland will lose its productive capacity. Similarly, plant growth depends in part on pollination and pest control, which can be aided by providing habitat for wild bees and beneficial predators. Beyond farms and ranches, thriving forests can support ecosystem services ranging from water provision, water treatment, and erosion control to air quality, carbon sequestration and outdoor recreation. But the production of food through intensive agricultural practices is often valued more than habitat biodiversity, leading to short-sighted decisions that ultimately reduce the capability of working landscapes to provide ecosystem services.

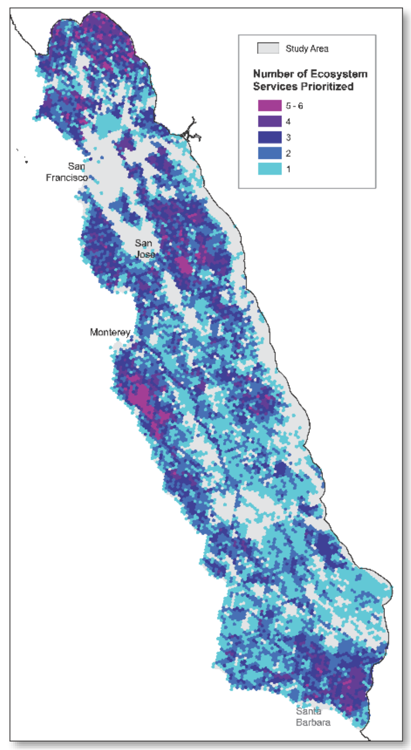

Figure 6: Ecosystem Services and Biodiversity "Hotspots" on California's Central Coast (reproduced from Chan, K. et al., 2006).

A Central California study analyzing biodiversity conservation in connection with six other ecosystem services— carbon storage, crop pollination, flood control, forage production, outdoor recreation and water provision—suggests several considerations for managing these tradeoffs.[81] Among these are the need to account for varying spatial distributions of different types of ecosystem services (see Figure 6) and the need to protect "hotspots" that offer multiple services. More broadly, the authors found that biodiversity conservation requires landscape-level planning, whereas other ecosystem services may be provided at smaller scales, and that biodiversity entails both opportunities and tradeoffs relative to other services.[82]

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[80] De Groot, R., et al., 2002; MA, 2005; Sukhdev, P. et al., 2010.
[81] Chan, K., et al., 2006.
[82] Chan, K., et al., 2006.

Complicating matters further, these opportunities and tradeoffs differ across the landscape. Some of their implications on rangeland and farmland, and in forests, are considered below.

- **Rangeland:** Approximately 34 million acres of rangeland is grazed in California. Rangelands provide multiple ecosystem services, including erosion control and water quality, groundwater recharge, forage for livestock, wildlife and pollination habitat, threatened and endangered species protection, outdoor recreation, and carbon sequestration.[83]

  Globally, rangelands house approximately 30 percent of terrestrial carbon stocks in addition to a substantial amount of above ground carbon stored in trees, plants and grasses.[84] Though significant attention is given to storing carbon in forests, rangelands potentially have unique carbon storage capacity as soils retain carbon over longer periods of time.[85] Soil organic carbon has historically been an indicator of soil health and fertility, and may play a significant role in addressing global climate change.

  Private markets are not fully established for rangeland ecosystem services. Obstacles include inadequate quantitative links between ecosystem service provision cause and effect, difficulties in monitoring implementation and lack of seller compliance mechanisms. But it may be possible to develop programs that overcome these obstacles, similar to the creation of wetland mitigation banks and the establishment of carbon markets.[86]

- **Farmland (Diversified Farming Systems):** Agricultural systems rely upon largely unremunerated ecosystem services including pollination, biological pest control, soil formation and fertility, nutrient cycling and water supply.[87] Diversified farming strategies, such as fostering biodiversity reserves near local agricultural communities, establishing habitat networks on non-farmed areas, integrating perennial crops into farm systems, and promoting farm practices that minimize pollution, seek to maintain, mimic

[83] Kroeger, T., et al., 2010; California Rangeland Conservation Coalition, 2016.
[84] Department of Energy, 2009; Food and Agriculture Organization, 2009; Flynn, A., et al., 2009.
[85] White, R., et al., 2000.
[86] Kroeger, T., et al., 2010. Among other benefits, these programs could provide funding to help manage wildfire risk. In areas where prescribed burning is not feasible, ranchers may need resources for brush removal and firebreaks. Bodrogi, L. (personal communication, September 29, 2017).
[87] Powers, A., 2010.

and harness the natural systems that provide these services.[88] As illustrated in Figure 7, these approaches differ significantly from conventional, monoculture-based farming.[89]

Figure 7: Full Belly Farm, Capay Valley, California (University of California Berkeley, 2016).

While some research suggests that yields from conventional farming are higher than those for organic production,[90] other studies indicate that diversified farming practices can improve yields and lower management costs.[91] Diverse and integrated approaches to food production create opportunities to increase farm production, incomes and habitat diversity.[92] Agroecology, for example, is a set of diversified farming practices that strives to mimic, balance and exploit the trade-off benefits of natural systems through polycultures, agroforestry, and integrating crop-livestock cultivation systems on farms.[93] Moreover, small-scale farmers around the world and in the United States already employ similar practices,[94] but are often not adequately compensated for their provision. Ecosystem service valuations and payments can encourage wider adoption of these approaches, allowing healthy ecosystems to benefit agriculture (and vice versa) while revitalizing rural economies.

- **Farmland (Integrated Pest Management):** Biologically complex, habitat-rich landscapes are associated with increases in natural predators beneficial to agriculture and

88 McNeely, J. and Scheer, S. 2002.
89 Kremen, C. and Miles, A., 2012; Kremen, C. et al., 2012.
90 De Ponti, T., et al., 2012.
91 Chan, K., et al., 2006; Bommarco, R., et al., 2013; Lin, B., 2011; Davis, A., et al., 2012; Liebman, M. and Schulte, L., 2015.
92 McNeely, J. and Scheer, S. 2002; Scherr, S and McNeely, J., 2008; Titonel, P. 2014.
93 Altieri, M., 1994; Altieri, M., 1999.
94 Tscharntke, T. et al., 2012.

pest control services.[95] Habitat management for predators, including support of alternative food sources and hibernation sites, refuge from pesticides, and provision of diverse microclimates, can help to control pest populations.[96] Even in conventional agricultural systems, farm edge practices can provide bird habitat, enable predators to forage for insect pests,[97] protect grass strip corridors used by predatory wasps,[98] offer habitat for predatory arthropods such as ladybugs (see Figure 8),[99] and otherwise promote predatory diversity of herbivores.[100] In the United States, services for integrated pest management have been valued at over $5.5 billion annually (in 2017 dollars).[101] Indeed, the biological control for a single invasive aphid in soybean production in only four states was estimated to be $84 million.[102] And along California's Central Coast, research has demonstrated that enhanced natural habitat and natural pest control promoted agricultural productivity in a region that produces most of the country's lettuce, broccoli and Brussels sprouts.[103]

Figure 8: Ladybug eats aphid (Cirrusimmage, 2016).

- **Farmland (Pollination)**: Approximately three fourths of the world's flowering plants, including many of the most commonly grown crops, rely on pollination to reproduce.[104] The worldwide value of this critical service has been estimated at $216 billion ($250 billion in 2017 dollars), representing 9.5% of world agricultural output in 2009.[105] Honeybees are by far the most prominent pollinators, both as wild and managed

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[95] Bianchi, F., et al., 2006; Holzschuh, A., et al., 2009; Chaplin-Kramer, R. and Kremen, C., 2012: Letourneau, D. et al., 2015a; Letourneau, D. et al., 2015b; Kross, S., et al., 2016.
[96] Landis, D., et al., 2000. See Bianchi, F., et al., 2006; Letourneau, D. et al., 2015a: Conversely, agricultural intensification that simplifies landscapes, enlarges field size and removes non-crop habitat risks the adequate functioning of natural systems of pest control.
[97] Batary, P., et al., 2010; Kross, S., et al., 2016.
[98] Holzschuh, A., et al. 2009.
[99] Geiger, F., et al., 2009
[100] Letourneau, D., et al., 2009.
[101] Losey, J., and Vaughn, M., 2006. Economic valuations of biological pest control for agriculture have been estimated by measuring changes in crop yields compared to output after experimental reductions in natural predators. The changes were modified by supply shifts and analysis of price elasticity. Letourneau, D., et al., 2015b.
[102] Zhang, W. and Swinton, S., 2012.
[103] Letourneau, D., et al., 2015a.
[104] National Research Council, 2007.
[105] Gallai, N., et al., 2009.

pollinators.[106] In the United States, pollination services from wild bees have been valued at more than $3 billion annually ($3.7 billion in 2017 dollars),[107] and by 2000, three million managed colonies provided services worth upwards of $15 billion ($21.8 billion in 2017 dollars), primarily for agricultural production.[108] In California, the value of pollination services enabled by wild bee habitat, including rangeland adjacent to farmland, has been estimated at between $889 million and $2.2 billion ($998 million and $2.4 billion in 2017 dollars).[109] For some individual counties, the value of wild bee pollination reaches into the hundreds of millions of dollars.[110] Pollination services are best supported in diversified and organic fields, landscapes with high quality habitats, and conventional fields near natural habitat.[111] Small scale farms using sustainable practices that integrate and promote wild insect pollinators with single species pollination (honeybees) have shown higher flower visitation and increased crop pollination.[112]

- **Forests:** Forests provide a range of ecosystem services including commercial forest products, water provision and treatment, soil stabilization and erosion control, improved air quality, climate regulation and carbon storage, biodiversity, and outdoor recreation.[113]

  The global value of forest ecosystem goods and services has been estimated at $4.7 trillion annually.[114] In the United States, payments for forest-based ecosystem services from all available sources of data totaled $1.9 billion in 2007 ($2.3 billion in 2017 dollars). Of this total, sales of forest wetland mitigation credits were $727 million, hunting leases and fees $410 million, conservation easements $315 million, conservation bank credits $34 million, wildlife viewing entrance fees $33 million, and sales of carbon offsets $1.7 million.[115] Timber is one of the most significant and controversial services, generating sales valued at $326 million for California in 2014.[116] Since the harvesting of trees diminishes other ecosystem services, the U.S. Forest Service now acknowledges this trade-off in its management practices so that forests are no longer viewed solely as a commercial product.[117]

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[106] Allsopp, M., et al., 2008.
[107] Losey, J., and Vaughan, M., 2006.
[108] Morse, R. and Calderone, N., 2000.
[109] Chaplin-Kramer et al., 2011a; Chaplin-Kramer et al., 2011b.
[110] In Fresno County, for example, pollination was estimated to contribute up to $313 million to agricultural production. Chaplin-Kramer et al., 2011a; Chaplin-Kramer et al., 2011b.
[111] Kennedy, C., et al., 2013.
[112] Garibaldi, L., et al., 2011; Garibaldi, L., et al., 2014; Garibaldi, L., et al., 2016.
[113] Krieger, D. 2001.
[114] Costanza, R., et al. 1997.
[115] Mercer, D., et al., 2011.
[116] USDA, 2015.
[117] Dombeck, M., et al., 2003.

A 2014 United Nations report on forest ecosystem services payments recommended the establishment of institutional frameworks, cost effective implementation and the bundling of services to decrease transaction costs.[118] In the United States, the Forest Service has analyzed payments for bundles of forest ecosystem services including carbon sequestration, watershed protection and biodiversity.[119] In California, a Forest Action Plan was completed in 2016 by the state's natural resource and environmental agencies, state and federal forest land managers, and other stakeholders.[120] The plan promises to foster implementation collaboration and direct investment opportunities toward comprehensive forest planning and management.

Biodiversity on working landscapes is bolstered by a variety of federal programs that provide ecosystem services payments to farmers and ranchers. The Landowner Incentive Program, funded through the U.S. Fish and Wildlife Service, supplements state funding to enhance, protect or restore habitat for at-risk species on privately owned lands.[121] The Partners for Fish and Wildlife Program works with landowners to restore wildlife and wetland habitats.[122] The Wildlife Habitat Incentives Program, administered by the USDA's Natural Resources Conservation Service, focuses on agricultural lands, private forests and tribal lands suitable for fish and wildlife habitat, including opportunities for restoration.[123] But many of these programs are siloed within individual agencies, making it difficult to integrate them into an overarching market for ecosystem services.

Payment for ecosystem services is directly linked to technological advancements in identifying and mapping these services across particular geographies. As discussed below, a number of mapping and modeling programs are already in use and being refined. Their capacities can be further integrated with input from stakeholders, scientists and policymakers, building the foundation for adoption of a single, accepted mapping program by the State of California.

V. Mapping Ecosystem Services

Scenario development and modeling of ecosystem services across the landscape opens avenues to classify them for purposes of creating markets. In this report, five ecosystem services—water supply, agricultural productivity, climate stability, recreational tourism and habitat

[118] United Nations, 2014.
[119] Mercer, D., et al., 2011.
[120] Forest Climate Action Team, 2016.
[121] USFWS, 2016a.
[122] USFWS, 2016b.
[123] USDA, 2016.

biodiversity—have been identified. Each has varying degrees of market potential for its ecosystem services and its interrelationships to other services and to human well-being.

The protection of natural capital—and investments devoted to conserving its capabilities—are contingent upon understanding its connection to ecosystem services. The most effective means of representing these relationships are through mapping and modeling tools capable of integrating vast amounts of scientific data across broad landscapes in ways that are accessible to local policy makers, stakeholders and general public.

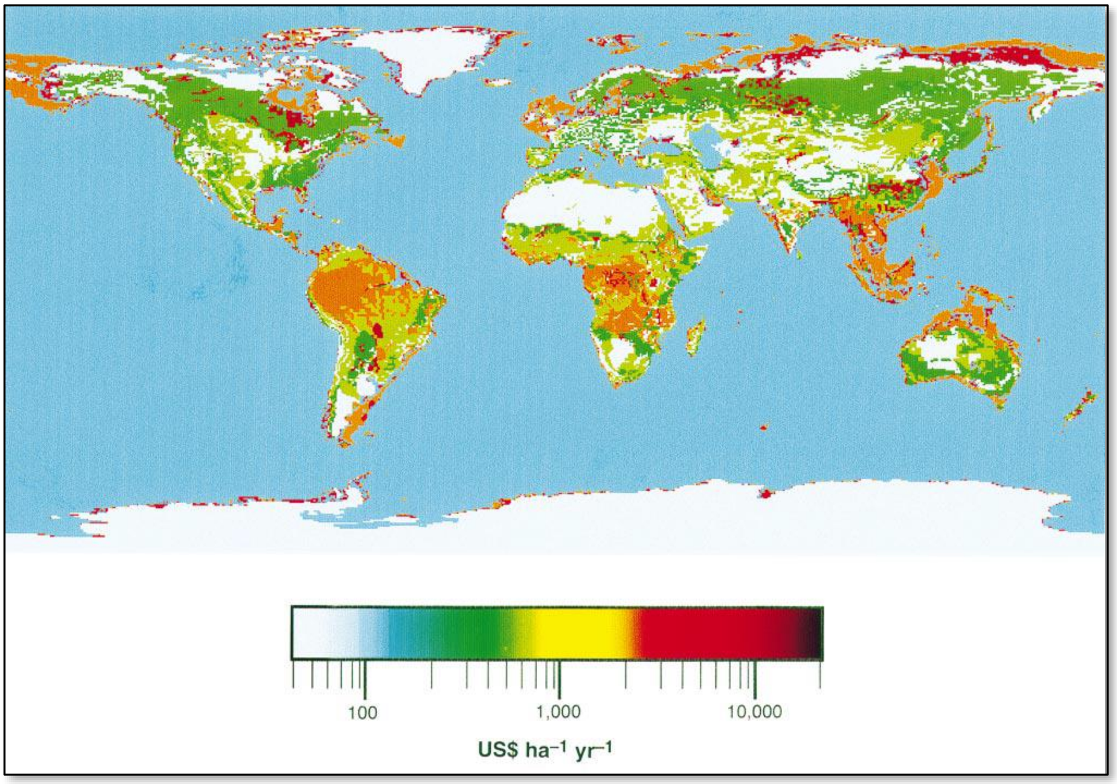

Figure 9: Global map valuing ecosystem service by biome (reproduced from Costanza, R., et al., 1997).

A 1997 study attempted to value ecosystem services around the planet by dividing the world into sixteen geographic biomes, and calculating the value per hectare that each biome contributed to the global economy (see Figure 9).[124] More contemporary approaches were illustrated in a 2010 landscape-level evaluation of ecosystem services in the Province of Quebec. This study divided its geographic region into six landscape types—corn-soy agriculture, feedlot agriculture, destination tourism, exurban, villages and country homes—and calculated the relative value of

[124] Costanza, R., et al., 1997. At a time when the gross global product was approximately $18 trillion per year, the study estimated that ecosystem services added $16 to $54 trillion of value per year, but noted that this was likely an underestimate.

specific ecosystem services for each type (see Figure 10).[125] An even more recent 2014 analysis established the "first-ever comprehensive economic valuation of natural capital and ecosystem services" in Santa Clara County by estimating natural capital contributions across a matrix of land types, taking into account not only natural resources and vegetation cover, but also development status and land use restrictions.[126]

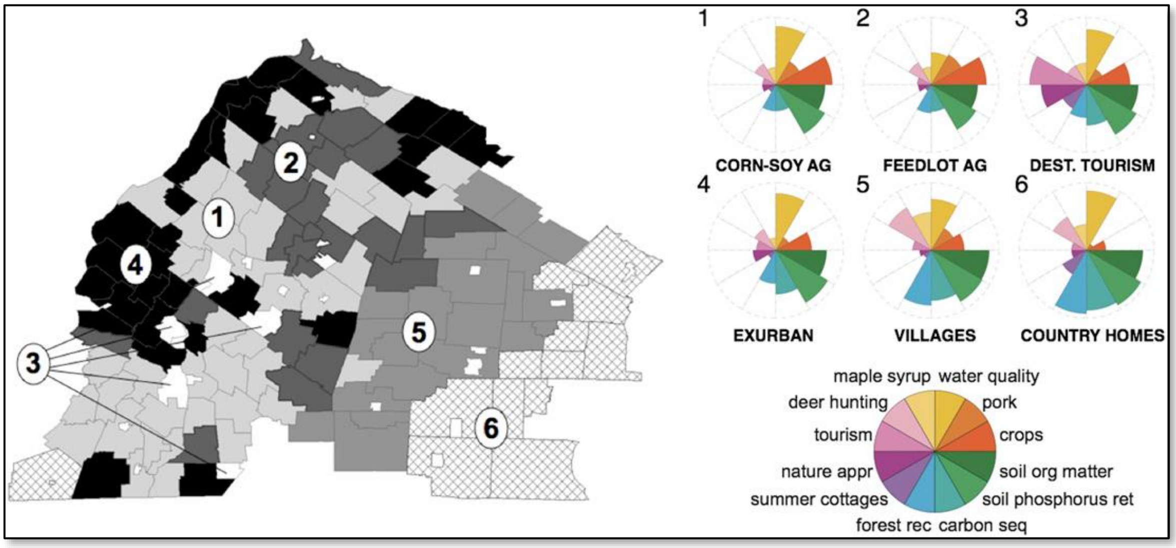

Figure 10: Ecosystem service values by landscape type in Quebec (reproduced from Raudsepp-Hearne, C., et al., 2010).

Recent years have seen significant progress in remote sensing, GIS and other mapping technologies,[127] and extensive research and data development on ecosystem services in specific regions of California.[128] Today, decision support tools allow farmers, ranchers, resource agencies, policymakers and other stakeholders to examine land use, infrastructure, economic

[125] Raudsepp-Hearne, C., et al., 2010. This study found that dividing ecosystem services into bundles enabled better understanding of the tradeoffs and synergies that result from land management decisions. For example, tradeoffs were identified between provisioning and regulating services, such as the effects of increased soil nitrogen from agriculture on water quality. Once identified, such tradeoffs can be acknowledged, assessed and managed.
[126] Batker, E., et al., 2014.
[127] Bocco, G., et al., 2001; Keane, R. et al., 2001; Pierce, F. and Clay, D., 2007; Nelson, E. and Daily, G., 2010; Seppelt, R., et al., 2011; Tweed, S., et al., 2007.
[128] See, e.g., SSP, 2010 (mapping and analyzing aquifer recharge, forest carbon storage, water yield and forage production in connection with habitat value and expected climate change in the Southern Sierra Nevada); Thorne, J., et al., 2014 (reporting on stakeholder-driven resource inventory of the San Joaquin Valley, and introducing a data repository that includes multiple layers on water, agricultural production and other ecosystem services); Batker, E., et al., 2014 (Santa Clara study valuing the county's natural capital assets at $386 billion, and finding that annual ecosystem services benefits to the local economy amount to between $1.6 and $3.8 billion).

development, fiscal feasibility analyses, food access, agricultural productivity, climate change and other variables at multiple scales.[129] These tools use graphic interfaces to display and analyze GIS data from existing ecosystem databases, models and assessments.[130] While limited by cost and data availability, they offer accessible, structured platforms to analyze problems by integrating data in areas ranging from hydrology and ecology to institutional and socio-economic factors.[131] In combination with other modeling software, decision support tools will be integral to any effort to map and value ecosystem services across California.

The Sacramento Area Council of Governments' (SACOG's) Rural Urban Connections Strategy (RUCS) is one of the more sophisticated decision support tools in use. Originally developed to evaluate land use decisions and transportation investments, RUCS is built around the insight that rural economies are directly dependent on ecosystem services. Covering a wide array of landscape types (see Figure 11), and incorporating crop-specific data from the University of California Agriculture and Natural Resources, it allows rural residents, resource managers and public agencies to model the impact of development scenarios on the rural, agricultural economy, including effects on resource conservation, recreation, and quality of life.[132]

[129] These technical capabilities and scientific assessments are often applied in primarily rural areas among sometimes skeptical constituencies and interest groups. Decision support tools open avenues to dialogue among stakeholders, including the farmers and ranchers, who will decide if an ecosystem service market is appropriate for their production practices and the natural resources found on their properties.
[130] Malczewski, J., 2006; Matthies, M., et al., 2007; Cravens, A., et al., 2012.
[131] Elmahdi, A. and MacFarlane, D., 2009; McIntosh, B., et al., 2011.
[132] SACOG, 2016; UC ANR, 2016b.

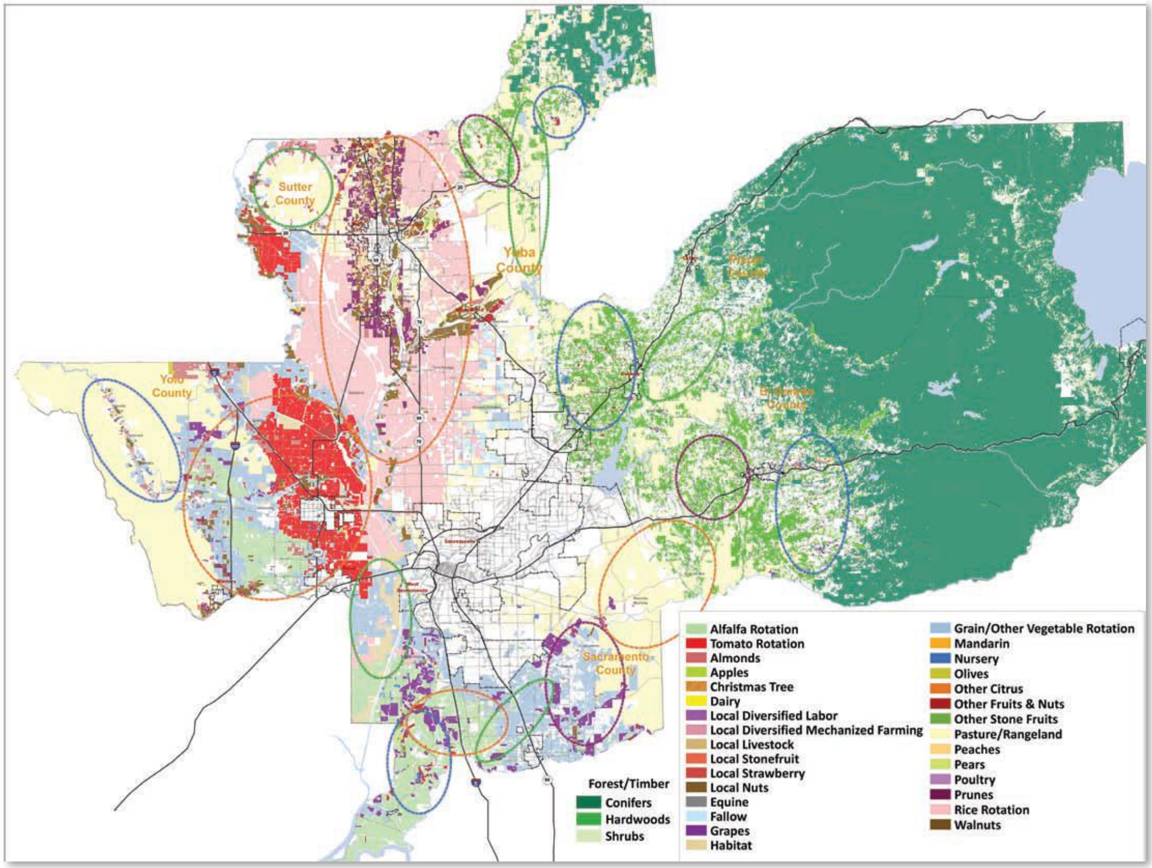

Figure 11: Sample RUCS map of landscape types in Sacramento region (reproduced from SACOG, 2016).

RUCS emphasizes the conservation benefits of farmland, encouraging incentives directed to farmers, and highlighting entrepreneurial opportunities around local food movements. A return-on-investment calculator uses the agricultural crop map to assign input values per crop for production costs, yield and price. The model's outputs on yield and value of production, demand for inputs (including labor, water, fuel, seed and transportation), and net returns can assist farmers, agricultural businesses, policy makers and the general public in understanding the economic benefits of conservation.

Further development of RUCS can serve broader constituencies and markets. Additional capabilities can be added as technology and scientific findings allow, including a growing suite of bundled services for groundwater recharge, carbon sequestration, renewable energy siting assessments, and the integration of biological services from natural habitat provision. An upgraded, open source platform can incorporate expanding system-wide ecosystem service valuations over time as technologies advance.[133]

[133] Decision support tools like RUCS can operate within a collaborative system of existing data clearinghouses, open model frameworks, and networks of scientists and institutions. Institutions like the Geospatial Innovation Facility at UC Berkeley's College of Natural Resources are

While RUCS and other decision support tools indirectly investigate ecosystem services, there is often no direct functionality within them to examine specific bundles of services. In contrast, the Natural Capital Project's Integrated Valuation of Ecosystem Services and Trade-offs (InVEST)[134] and Artificial Intelligence for Ecosystem Services (ARIES)[135] are both open source modeling tools that estimate the biophysical outputs of multiple ecosystem services across landscapes. The Natural Capital Project is a partnership between Stanford University, the University of Minnesota, The Nature Conservancy, and the World Wildlife Fund bringing together academics, software engineers, and professionals from those institutions and organizations. The Project works with international organizations, global corporations and nation states on sustainable development and ecosystem planning. ARIES was started in 2007 as a collaboration between the University of Vermont, Earth Economics and Conservation International, with funding from the National Science Foundation. ARIES holds two-week, intensive instruction symposia for scholars, practitioners and IT experts from around the world on its methods to quantify and value the flows of ecosystem services.

InVEST is a scenario-driving modeling tool that incorporates demand for services and estimates of production of services in both biophysical and monetary terms.[136] Its open source software maps and values the goods and services from nature. InVEST considers how an ecosystem's structure and function affect the flows and values of ecosystem services, including water quality, water provision for irrigation and hydropower, flood mitigation, soil conservation, carbon sequestration, pollination, cultural values, timber and non-timber forest products, agricultural products, and residential property values.[137] In addition to conservation and climate planning, its outputs can be used to establish payments for ecosystem services.[138] ARIES, in contrast, uses a benefit transfer methodology referencing land use and land management practices.[139] It establishes values for specific locations by referencing studies from similar landscapes. While often less expensive than production modeling approaches, ARIES is also less responsive to estimating changes under differing future scenarios and is reliant upon the similarities of

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sources of expertise and capacity that may be able to fill some of the remaining gaps in integrating mapping technologies and spatial data.

[134] Kareiva, P., et al., 2011.

[135] ARIES, 2016.

[136] Nelson, E., et al., 2009; Tallis, H., et al., 2010; Kareiva, P., et al., 2011.

[137] Nelson, E., et al., 2009.

[138] Tallis, H., et al., 2010.

[139] Benefit transfer approaches such as ARIES identify benefits in per unit tables of habitat type, which are then extrapolated to other contexts, whereas production function methodologies build models to predict local ecosystem service supply. In agriculture, similar production functions combine water, fertilizer and labor to estimate crop yield. Kareiva, P., et al., 2011.

referenced site-based studies used to generate the model's ecosystem service valuations for the given landscape.[140]

The major gap involving decision support tools like RUCS and ecosystem services modeling tools like InVEST and ARIES is that they have not yet been integrated into a combined, open source system.[141] For example, RUCS currently focuses on the Sacramento region alone, as opposed to California as a whole. If a statewide ecosystem services platform could be made available to planners, resource managers and the public through a single, accessible, open source website,[142] Californians would have the tools they need to map the increasing layers of ecosystem services, bundle their values and better account for the state's natural capital assets.

VI. Next Steps for Policymakers

To protect natural capital, it will be essential to link data on ecosystem services with payments to farmers, ranchers and other land stewards for the conservation and sustainable management of working landscapes. Establishing these links will require catalyzing public investments, engagement with local communities, and recognition of the economic realities of agricultural production. Implementing programs, and their scientific justifications, cannot be distanced from the farms, ranches and other landscapes where they are slated to be delivered. Ultimately, those who steward California's natural capital must benefit from conserving it.

To realize this goal, policymakers should take the following steps:

<u>Create and Expand Markets for Ecosystem Services</u>

- **Use Enhanced Infrastructure Financing Districts (EIFDs) or Similar Mechanisms to Create Local or Regional Markets for Natural Water Infrastructure:** Incorporate the costs of acquiring or restoring specific natural capital (e.g., a particular upper watershed

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[140] Nelson, E. and Daily, G., 2010.

[141] This combination holds essential elements of environmental and resource decision making through their ability to integrate diverse datasets, quickly and effectively communicate outcomes, develop scenarios explicitly in a spatial domain, and allow intuitive and effective interactions between stakeholders from agricultural, climate, economic and natural resource audiences.

[142] Such a platform could host a suite of integrated tools to support interactive visualization, public decision-making platforms, fiscal return analyses, and transparency of government data. Maps and findings could compare one land use scenario with another, balancing costs and returns against estimates for habitat loss/gain, net carbon sequestration, groundwater recharge and other services. Users could interactively explore how these factors interact with productivity, carbon, and cost, providing valuable data for ecosystem services markets at the local and regional scales.

forest or riparian corridor) into water fees paid by end users served by that capital, such that each user pays a proportional share of the cost of conserving it.[143] This approach could potentially be implemented through EIFDs created by local governments, although other funding mechanisms would need to be devised for long-term management needs.[144] It could draw on existing water infrastructure funding, particularly if policymakers choose to invest preferentially in natural infrastructure, as opposed to additional built infrastructure.[145] It could also draw on corporate giving programs in which corporations within each watershed actively participate in restoration efforts.

- **Expand Existing Markets for Farmland and Rangeland Conservation:** Provide additional funding and more robust conservation options for existing markets that support the long-term viability of agriculture, such as those created by the Farm Bill, the Williamson Act and the Sustainable Agricultural Lands Conservation Program (SALCP).[146] Recently proposed legislation, for example, would fund subvention payments to counties to balance out property tax revenue lost to Williamson Act contracts,[147] and provide for contract terms of up to fifty years (as opposed to the current

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[143] One model of this approach was Denver Water's response to wildfires that burned nearly 150,000 acres of forest and subsequent rainstorms that deposited a million cubic yards of sediment in local reservoirs. Working with the U.S. Forest Service, Denver Water invested $33 million in forest restoration and watershed improvement projects covering over 38,000 acres, at a cost of $1.65 a year for the average residential water user. This work has helped to protect the mountainsides and rivers that deliver Denver's water, while also enhancing wildlife habitat and recreational opportunities. Denver Water, 2016.

[144] EIFDs can fund the development or acquisition of capital, but not the long-term costs of operating it. Gardiner, C. (personal communication, May 8, 2017).

[145] One model for strategic investments in natural water infrastructure is a plan put forward by Pacific Forest Trust (PFT) to conserve and restore 10 million acres of the Klamath-Cascade Range, of which 4.5 million acres are in private ownership. Water from this region supports $37 billion in agricultural production (almost one-third of the state's total) and is supplied to 25 million individual users. Over the next two decades, this water demand is expected to increase 33 percent. PFT's proposal to conserve and restore the watershed has an estimated cost of less than $3.1 billion (the same capital expenditure for constructing two desalination plants to provide less than 3 percent of the water that the Sacramento River currently provides). Beyond providing water, numerous other ecosystem services could result from this investment, including increased biodiversity, opportunities to diversify the forest-based economy, management of carbon sinks as mitigation for carbon emissions, and maintenance of appropriately scaled biomass energy production. Land trusts could likely acquire the natural infrastructure that provides these benefits for less than the cost of building additional dams and canals. Wayburn, L. and Chiono, A. 2016.

[146] As noted above, expanding markets for agricultural conservation will require greater buy-in from farmers and ranchers. Studies have already identified rancher preferences in ecosystem services payment programs, see Cheatum, M., et al., 2011b. Similar research could help to reach farmers, vineyard owners and others.

[147] See SB 435 (pending).

standard of ten to twenty years).[148] Additional approaches could include increasing federal funding for Farm Bill programs and state funding for SALCP, ensuring that conservation programs support long-term stewardship of land and water resources (as opposed to acquisition alone), and coordinating investments geographically to support compact growth within existing communities.[149]

- **Expand the Market for Habitat Conservation:** To provide more thoroughgoing protections for biodiversity, build on Habitat Conservation Plans, Natural Community Conservation Plans, and partnerships like the Central Valley Habitat Exchange to expand investments in habitat conservation. Focus not only on protecting threatened and endangered species, but also species on the cusp of being listed.
- **Expand the Market for Carbon Sequestration:** Expand existing investments in carbon sequestration, and fully fund the Healthy Soils Program. In addition to the carbon sequestration potential of forests and woodlands, a growing body of work suggests that significant amounts of carbon can be stored in soil.[150] Expanding investment in the Healthy Soils Program to support agricultural practices that add to these stocks could help to create a broader market for carbon sequestration while also creating additional revenue streams for farmers and ranchers to adopt more ecologically beneficial agricultural practices.[151] Given the well-established relationship between soil organic matter (of which an average of 50 - 56% is carbon) and the ability of soils to retain water,[152] such a market could also contribute to watershed function, natural groundwater recharge and overall water provision.
- **Expand and Integrate Markets for Agricultural Practices that Provide Multiple Ecosystem Services:** Building on federal investments, such as WHIP and EQIP, and state programs, such as the Healthy Soils Program and the State Water Efficiency and Enhancement Program (SWEEP), provide comprehensive, coordinated funding for a wide range of agricultural practices that reduce GHG emissions, contribute to water availability and support biodiversity. Examples could include creating biodiversity reserves near local agricultural communities, establishing habitat networks on non-farmed areas (including habitat for wild bees and other beneficial species), integrating

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[148] See AB 925 (pending).
[149] An expanded version of RUCS could draw on existing data and analyses to help identify the most promising investments. Farmland Mapping and Monitoring Program (FMMP) data, combined with information on land use and prospects for urban development, can be used to locate highly productive farmland in danger of conversion. DOC, 2017b. The Nature Conservancy has developed a prioritization process to map the most important rangelands to conserve in California, see Cameron, D., 2007, and these tools are supplemented by regional and local conservation planning efforts in much of the state. See, e.g., SSP, 2010 (identifying conservation priorities for the Southern Sierra region).
[150] Ryals et al., 2014; see also Ryals et al., 2016.
[151] De Gryze, S., et al., 2009.
[152] Rawls et al., 2003; Huntington, 2007; Pribyl, 2010.

perennial crops into farm systems, adopting irrigation and land management approaches that minimize water use and pollution, and designing farming systems to mimic natural systems.[153]

Support Participation

- **Provide Regulatory Incentives to Support Market Participation:** Create a regulatory framework that increases demand for specific bundles of ecosystem services, lowers barriers to participation and helps link buyers to sellers. For example, just as AB 32 and SB 32 drive policy and investments through state-level GHG reduction targets, state-level land conversion reduction goals (and associated targets for conservation funding) could provide an impetus for valuing and protecting ecosystem services. Creating closer links between CEQA mitigation requirements and regional conservation planning could help support markets for working lands conservation, watershed stewardship and other investments. And these regulatory incentives could be strengthened by ensuring that agencies adopt clear and consistent metrics for the benefits provided by working lands.[154]
- **Design Programs to Be Responsive to Participants' Needs:** Ensure that stakeholders are vested in ecosystem services markets by incorporating citizen science, traditional ecological knowledge, rural needs, and participatory budgeting into program design. Innovative programs, such as the creation of "food commons" and adapting community land trusts to agricultural regions could comprehensively link rural economic development, affordable housing, agroecology, public health, and broader awareness of the importance of ecosystem services.[155] Ongoing input could help refine programs over time.
- **Provide Technical Assistance:** From applying for funding to implementing land management practices, ensure that technical assistance is available to help farmers, ranchers and other landowners participate in ecosystem services markets. As NRCS programs like EQIP illustrate, providing technical assistance can greatly expand access to ecosystem services markets.

[153] McNeely, J. and Scheer, S. 2002.
[154] For example, the Air Resources Board could choose a specific tool to measure the GHG reduction benefits of agricultural conservation.
[155] Food Commons. 2011; Yuen, J. 2014; Food Commons Fresno. 2017. Projects designed to promote community ownership, including through direct public offerings of stock, land trust acquisitions of farmland and other assets; and economic activity purposefully designed to vertically integrate businesses along the food value chain.

Enhance Mapping Capabilities

- **Support Mapping Technology Integration:** Provide funding and technical support for the integration of RUCS and other tools into an open source, statewide system for mapping ecosystem services. In addition to expanding RUCS geographically, incorporate data, models and technical approaches from other systems where necessary to fully capture the benefits of biodiversity and other categories of ecosystem services.

VII. Conclusion

While much work remains to be done, California is uniquely positioned to establish integrated, functioning markets for ecosystem services. From investments in conservation easements to a pioneering cap-and-trade program, ecosystem services markets are already in place or forming.

Policymakers seeking to expand them can draw on the expertise of world-renowned research universities, state and regional planning agencies, and a host of partners, including resource conservation districts and land trusts. And while there are still barriers to widespread acceptance by farmers and ranchers, markets that incorporate their input and offer robust financial incentives are likely to have broader participation.

Achieving these goals will require sustained commitment, research and investment. This report does not offer a comprehensive roadmap for getting there, or a response for every challenge that will arise on the way, but its policy recommendations address the current gaps in realizing ecosystem services markets on working landscapes.

If successfully implemented, such markets can help to protect the natural systems that provide water and food, maintain a livable climate, support outdoor recreation, and confer countless other benefits. They can direct much needed investment to farms, ranches and other working landscapes, helping to revitalize rural areas and bridge the economic gaps between regions. Ultimately, California’s implementation of ecosystem services markets can serve as a model for other states and nations.

VIII. Table of Authorities and References

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1) <u>California Statutes</u>

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SB 32 (codified at Cal. Health and Safety Code § 38566.

Sustainable Communities and Climate Protection Act of 2008 (SB 375), 2008 Cal. Stat. Ch. 728 (codified at Cal. Gov. Code §§ 14522.1, 14522.2, 65080, 65080.01, 65400, 65583, 65584.01, 65584.02, 65584.04, 65587 and 65588 and Cal. Pub. Res. Code §§ 21061.3, 21155 et seq., and 21159.28).

2) <u>Pending Legislation</u>

AB 925 (Frazier).

SB 435 (Dodd).

3) <u>Local Ordinances and Other Authorities</u>

City of Davis Municipal Code §§ 40A.03.010 *et seq*.

Greater Salinas Area Memorandum of Understanding

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