TECHNICAL REPORT

The Potential Value of Nonmarket Benefits Provided by Avocado Orchards in California

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Table of Contents

1. Executive Summary

California avocados provide different types of economic value. Standard values include the popularity of eating avocados by consumers, not to mention their tremendous nutritional value, and business income generated by producers and related businesses. However, California avocado production potentially provides a range of other benefits to regional economies that are not reflected in these standard measures of economic activity. This includes ecosystem services such as provision of open space, erosion control, groundwater recharge, carbon sequestration, and air quality, but also potential roles in fire suppression and contribution to national economic goals such as balance of trade. These important features of avocado production are called nonmarket benefits because they are not directly bought and sold in a market.

ERA Economics prepared a report summarizing example nonmarket benefits in 2014 (ERA 2014). This report is expanded to include additional nonmarket benefits and updates to values based on more recent studies conducted since 2014. This updated report describes and quantifies (establishes a monetary value) some important nonmarket benefits associated with avocado production in Southern California. It includes an inventory of relevant publications that have established the value of nonmarket benefits, describes how benefit values should be interpreted, and provides recommendations for future technical work to refine these values for California avocados. Selected nonmarket benefits potentially provided by California avocados included in this study are:

- Fire suppression
- Carbon sequestration
- Trade balance
- Erosion control
- Open space provision
- Air quality

Fire suppression. Southern California wildfires burn through seasonally dry native vegetation and can cause considerable property damage and loss of life. The 2020 fire season has seen record-setting blazes across the state. California avocado orchards, with their relatively moist tropical vegetation, can help protect adjacent properties and act as a firebreak, thereby reducing property damage through expediting fire containment. The average cost for constructing a firebreak is around $200 to $2,000 per acre with higher costs if erosion control structures must be included. Existing California orchards located near communities can provide a cost savings benefit in firebreak establishment and management.

Carbon sequestration. The value of carbon sequestration is an important nonmarket benefit attributed to California avocado orchards. A 2012 study prepared by researchers at UC Riverside calculated the potential for carbon storage in avocado orchards, and highlighted areas for future research. Carbon sequestration is increasingly important with the young, but growing carbon market in California. Recognized carbon offset opportunities in California do not currently include orchards (dairy methane digesters and rice field management practices are two potential agricultural carbon sinks). If specific management practices for avocado orchards can become an approved carbon sink, this would provide an important benefit in the carbon offset credit market.

Trade balance. The overall U.S. trade deficit in August 2020 was $67.1 billion, the highest deficit since 2006. Excluding services, the trade deficit was $83.9 billion, the highest ever recorded. Rapidly increasing per-capita avocado consumption coupled with steady production in California mean that avocados are a small contributor to the growing trade deficit. Any loss of avocado acreage in California is largely offset by increasing acreage in Mexico or South America, and imports to the U.S. programs and policies that could encourage California production would reduce the trade deficit for avocados specifically and provide a small reduction to the broader U.S. trade deficit.

Erosion control. Erosion control benefits include improved water quality, decreased soil loss, and preservation of wildlife habitat. Where natural ecosystems historically provided benefits of retaining soil and preventing erosion, irrigated agriculture now provides some of these amenities. Erosion control is a central component of avocado orchard establishment and production on steeper slopes in Southern California, including seeding and preservation of organic residue, and developing on-farm drainage and transportation systems.

Open space provision. Open space generally includes land such as parks and natural areas that may be used for recreational purposes, wetlands and forests that supply wildlife habitat, and farms and forests that provide aesthetic benefits to nearby residents. Open space also limits urban density, which reduces pressure on city utilities, roads, and other infrastructure. California avocado orchards located near urban developed areas may provide some aesthetic and related benefits.

Air quality. Trees and vegetation help improve air quality by directly removing pollutants such as nitrogen dioxide (NO_2), carbon monoxide (CO), ozone (O_3), particulate matter less than 10 microns (PM_{10}), and sulfur dioxide (SO_2) from the air. Agricultural trees, vines, and plants are able to remove some of these pollutants from the air and consequently improve regional air quality.

A literature review was conducted to identify the potential value for each nonmarket benefit included in the study. The value of a nonmarket benefit for an avocado orchard is always relative to an alternative land use. For example, if native trees are cleared to plant an avocado orchard this would reduce any air quality and carbon sequestration benefit attributable to the avocados. In contrast, orchards planted in areas that would otherwise be developed into homes or businesses would provide a greater relative nonmarket benefit. The per-acre values presented in this report are from other studies that may not directly consider alternative land uses specific to avocados in

California. A general range of benefit values is provided. A natural extension of this analysis is to develop a benefit-transfer analysis that would identify specific values that would apply to orchards located in specific parts of the state.

Table 1 presents the range of nonmarket benefit values, the most relevant study (or studies), and summary notes describing how to interpret the value. This report is not intended to be an exhaustive treatment of all potential nonmarket benefits attributable to avocado orchards. For example, orchards may provide additional benefits for stormwater infiltration through greater groundwater recharge and reduced flood management costs. In addition, this study also does not evaluate all alternative land uses to establish location-specific benefit values. These considerations are left for future work.

Table 1. Economic values for nonmarket benefits provided by selected avocado orchards

Service	Value Range (2020 $)	Units	Study	Notes
Firebreak [a]	$200 - $2,000	Acre/yr	Loomis et al. (2016); USDA NRCS (2014)	Orchards that can be utilized as a potential firebreak; location-specific
Carbon Sequestration	$130 - $485	Acre/yr	McPherson et al. (2016)	Currently no carbon offset credits for orchards; future value depends on carbon market price and ability to generate credits
Trade Balance	Not Quantified	n/a	n/a	Trade balance would be measured by the reduction in avocado trade deficit
Erosion Control [b]	$465 - $990	Acre/yr	McPherson et al. (2016); McPherson et al. (2000)	Applies only to orchard acres in areas with erosion risk
Open Space [c]	$490 - $1,100	Acre/yr/home	Kuminoff (2009)	Applies only to acres near residential development
Air Quality	$830 - $1,810	Acre/yr	McPherson et al. (2016); Nowak et al. (2014); McPherson et al. (2000); Scott (1998)	Applies to orchard acres that would have otherwise been developed

[a] Benefits do not include any additional value from prevented property damages or loss of life; no benefits values for these considerations were identified in the existing literature.

[b] Benefits associated with water treatment and flood control. Values assume 145 trees per acre.

[c] Benefits associated with agricultural cropland within ¼ mile of residential homes. Values assume benefits accrue over 15 years at 3% discount rate.

A primary analysis of ecosystem service values was not performed. Rather, academic and governmental studies were reviewed to identify studies that have established the value of nonmarket benefits in other areas that are applicable to California avocado production. The values should be interpreted utilizing the potential range, subject to additional analysis (e.g., benefit-transfer analysis) that would result in benefit values that are specific to avocados grown in different regions of California and under specific management practices.

The findings of the literature review can be summarized as follows:

- Orchards located near high-risk fire areas can provide firebreak benefits valued at $200 to $2,000 per acre in capital costs alone. Additional operating and maintenance costs would increase this estimated benefit value.
- Avocado orchards have the potential to provide carbon sequestration with a non-market gross value of $130–$485 per acre per year.
- The U.S. runs a trade deficit for avocados. Policies that would encourage increased U.S. production of avocados would reduce this trade deficit.
- An acre (or portion thereof) of orchard in an area affected by erosion could provide a non-market value of $465–$990 per acre per year.
- An acre (or portion thereof) of agricultural cropland within ¼ mile of residential housing could provide an open space non-market gross value of $490–$1,100 per acre per year per home.
- An orchard could generate an air quality non-market gross value of $830–$1,810 per acre per year.

This review of existing literature suggests that avocados can provide important nonmarket benefit values to local economies across the state. Many of these benefits (e.g., improved air quality and firebreaks) provide a broader public benefit to society. This suggests the potential for designing programs and policies that would encourage some public investment in these benefits that are provided by private California avocado farming activities. As described throughout this report, the exact value of these benefits is location and context specific. The comprehensive literature documenting and quantifying significant potential economic benefits is evidence of important public economic value that should be an important part of future public policy decisions and potentially incentivizing expanded avocado (or other orchard) production in parts of the state.

2. Introduction

Since the 1950s the agricultural areas in Southern California, including Los Angeles, Orange, Riverside, San Bernardino, San Diego and Ventura Counties, have experienced a shift in land use from agriculture to urban development. Prior to the 1950s, Los Angeles County consistently produced a substantial share of California agriculture (Johnston 2003). After World War II an influx of suburban development and industrial growth along the Southern California coast began to crowd out agricultural lands. Remaining agricultural areas typically include high-valued crops, including avocados, citrus, and nursery products. With high irrigation water costs and the pressures of urban expansion these are the only economically viable crops. Table 2 summarizes the harvested acreage in Southern California counties since 1980.

Table 2. Total acreage harvested in selected California counties, 1980-2018

County	1980	1990	2000	2010	2018
	Acres Harvested				
Los Angeles	51,416	13,498	22,984	2,101	172
Orange	24,508	18,373	11,328	4,087*	1,252
Riverside	242,124	254,877	224,348	176,948	172,279
San Bernardino	63,061	43,381	38,717	22,810	34,542
San Diego	66,177	62,935	58,043	60,639	52,658
Ventura	119,920	106,446	99,157	96,529	93,461
Total	567,206	499,510	454,577	363,114	354,364

* Excludes barley, misc. grains, and beans.

Source: USDA NASS County Agricultural Commissioner Reports, 1980-2018. All acreage estimates exclude pasture and forage crops.

The conversion of land use to agricultural and urban use places strain on natural ecosystems. Natural ecosystems provide habitat for wildlife and improve air, water, and soil quality, among other intangible benefits. Agriculture can provide some of the benefits of natural ecosystems and these benefits may generate a positive value for society. These are called nonmarket benefits because they cannot be purchased in a market, so it is difficult to observe a price (value). These benefits are often associated with the maintenance of various ecosystem functions that provide benefits to society, such as erosion control, fire prevention, water and air purification, recreational opportunities, and aesthetic benefits. Such nonmarket benefits are often referred to as ecosystem services.

This report is an update to a reported developed for the CAC in 2014 (ERA Economics 2014). It summarizes the updated results of a literature survey of economic studies that have attempted to value erosion control, air quality, and open space ecosystem service values provided by agricultural lands. The updated report also includes a review and discussion of other nonmarket benefits, including firebreaks and carbon sequestration, as well as a summary of potential balance of trade benefits for avocados produced in California. It also includes a discussion of how to interpret the benefit values, and how those values could be updated and expanded in future work commissioned by the CAC.

2.1 Economic Valuation Methodology

Economists typically use one of the following methods to value nonmarket benefits: avoided cost, hedonic pricing, or contingent valuation. A summary of each methodology is provided below.

The **avoided cost** methodology estimates values of ecosystem services based on the costs of avoiding damages due to lost services (Costanza et al. 2006). This methodology assumes that the costs of avoiding damages must be worth at least what people would pay to replace such services. It is most appropriate in cases where damage avoidance expenditures have been, or will be, made. This approach is commonly used to estimate the value of non-market goods that provide a public safety benefit, such as erosion control, flood control, and fire suppression. Given the cost of a public safety event (e.g., a flood or fire), the value of the non-market benefit may be estimated from the reduced probability of occurrence.

The **hedonic pricing** methodology is used to estimate the value of ecosystem services that directly affect prices of marketed goods, such as residential housing prices (Costanza et al. 2006). This method assumes that people value the individual characteristics of a good, including those related to the ecosystem service in question, such that market prices correctly reflect such values. The hedonic method relies on econometric (statistical) analysis to tease out the value of non-market goods by observing how the price of a related marketed good changes. For example, the value of agricultural open space can be inferred by an analysis of the value of residential homes near the agricultural space in question.

The **contingent valuation** methodology is a flexible approach that may be used to estimate virtually any ecosystem service value of interest. It is most often used in cases where other approaches are not feasible. The contingent valuation approach uses a carefully structured survey of consumers of the non-market good to elicit the value that they place on the good in question. This method asks participants to directly state their willingness to pay for the specific service based on various hypothetical scenarios. Reliable estimates require a survey that is carefully structured to avoid survey (self-reporting) bias and a minimum sample size of 100.

2.2 Interpreting Nonmarket Benefit Values

Nonmarket benefit refers to the monetary value of product attributes that are not directly traded in a market. The concept is simple and intuitive: people value some things that are not directly bought and sold in a market. For example, fresh air and scenic landscapes. However, valuation (monetization) of nonmarket benefits is more difficult, requiring one or more analytical methods.

Methods include direct survey approaches, valuation based on costs paid to receive a nonmarket benefit, hedonic pricing (land price) methods, and alternative cost approaches.

An important concept for applying nonmarket benefits is establishing alternative land use. A nonmarket benefit is the value relative to some other, alternative land use(s). The per-acre values presented in this report are from other studies that do not directly consider alternative land use specifically for avocados.

Everything is relative and case specific. In situations where the alternative use is residential or other urban, the non-market values would generally apply. However, if the alternative use is native vegetation or other open space, the values would generally not apply. That is, in cases where orchards are developed on previously undeveloped land, this conversion may have a smaller net non-market value than the figures shown in this report. If an orchard on steep terrain is being abandoned and the future land use does not control erosion, the erosion benefits described herein would apply.

A recommended next step for this analysis would develop a benefit-transfer analysis to adjust for these differences. A benefit-transfer analysis takes studies that were developed in other areas, regions, and contexts and adjusts them to be appropriate for the study area and land use in question. For example, a valuation of open space benefits for agricultural lands in Oregon would be adjusted to be applicable for the benefit of open space avocado orchards in Southern California. Importantly, this would account for alternative land uses so that the nonmarket benefits would be relevant to land uses, locations, and times in Southern California.

2.3 Outline of Report

This report is divided into six sections for each nonmarket benefit: firebreaks, carbon sequestration, trade balance considerations, erosion control, open space and air quality. Each section provides the following for the specific ecosystem service in question: (i) a summary of the benefits provided, (ii) an explanation of the standard economic valuation method(s) employed by the researchers and how to interpret values, (iii) a summary of ecosystem service value estimates obtained from the literature (firebreak, carbon sequestration, trade balance, erosion control, open space, air quality), and (iv) a discussion of recommended next steps.

3. The Value of Firebreaks

Southern California wildfires burn through seasonally dry native vegetation and can cause considerable property damage and loss of life. Orchards, including avocados, with relatively moist tropical vegetation, can help protect adjacent properties and act as a firebreak, potentially reducing property damage. This has the potential to provide significant nonmarket benefit values to local communities.

California avocado orchards will burn in a fire, but they burn less rapidly than dry native vegetation, providing a benefit to firefighters and local communities (Prevor 2007). Faber (2016) provides additional discussion of these benefits, stating that "avocado orchards are notable for their ability to actually reduce fire hazard and slow major fires as has been shown in fires in San Diego, Ventura and Santa Barbara."

Firebreaks are not always effective against wildfires. As has been the case in 2020, large fire events can breech even a wide firebreak. The Southern California Thomas fire, until recently the second largest on record, blew over several firebreaks including one that ran on a ridgetop for 13 miles. In addition to assisting in slowing/stopping the spread of the fire, Syphard et al. (2011) note the importance of firebreaks for providing access to firefighting equipment. This is particularly important in densely populated areas such as Southern California.

A well-maintained firebreak that provides access for firefighting is critically important during a wildfire event. Orchards are typically well managed with vegetative growth limited. Therefore, orchard undergrowth is limited and managed at the cost of the private grower. Management practices can augment the value of an orchard as a firebreak. For example, minimizing vegetative growth and running orchard sprinklers during a fire can and has helped reduce fire damage.

In addition to providing value during a fire, orchards potentially provide additional value for local passive management. Orchards can be incorporated into existing land use and fire planning. Fire planning would recognize and incorporate developed orchards. A more active management approach could encourage development of new orchards in areas with high fire risk or in need of fire equipment access points. This type of land use conversion could be incentivized through potential state, local, and third-party NGO funding sources and potential easements. No specific programs that would support this type of land use change were identified as part of this initial study. However, considering the catastrophic fire year in 2020, this would be an area to monitor in the future.

3.1 Valuation Methods

The value of an orchard as a firebreak can be calculated using an alternative cost approach. The alternative cost concept recognizes that when multiple actions have the same desirable result, the benefit of one action is its cost savings relative to another. The value of an orchard as a firebreak is the avoided cost of developing alternative firebreaks plus any avoided damages or loss of life because of better access during a fire event.

3.2 Values from the Literature

A review of existing studies identified some attempts to establish the value of agricultural lands as firebreaks. It seems likely that this will become a more active area of research with the increased focus on fires in the Western U.S.

The USDA Natural Resource Conservation Service (NRCS) published a study in 2014 that provides fairly detailed budgets for costs of constructing a bare-ground firebreak. The study was focused on lands in Missouri. The most comparable firebreak cost for California is likely for development on steep slopes of 15 percent or more. The estimated development costs include 4 hours of bulldozer time per 1,000 foot of break, and around $1,200 for erosion control structures. Excluding erosion control, the per acre cost is around $1,900.

Loomis et al. (2016) develop a statistical (regression) model of fire management activity costs from Forest Service Activity System (FACTS) data. They estimate the cost per acre of a fuel break in Southern California as a function of acreage, and whether or not the location is in a wildland/urban interface, and whether or not the fuel break is in a metropolitan county. The estimated cost to develop a break is about $450 per acre in a metropolitan county with a wildland-urban interface, and around $300 per acre in other areas.

Calkin and Gebert (2006) also developed a regression analysis of fuel reduction projects in the Western U.S. Their study considered factors including acreage, elevation, fuel load, region, fire regime, and wildland-urban interface. They developed an average cost of $213 per acre. However, the study also emphasizes the wide range of costs in different conditions.

Table 3 summarizes the results of the primary literature review. Other studies were reviewed but were not included in this report because they were not applicable to conditions in California. The average cost per acre for constructing a firebreak is $200 to $2,000 per acre. If erosion control is required, which is typically the case in regions where avocados are produced in California, this would result in additional costs. In addition, the costs summarized in Table 3 do not include additional maintenance costs for the firebreak. Inclusion of these costs would make orchards appear more favorable since both maintenance and construction costs would be part of orchard development.

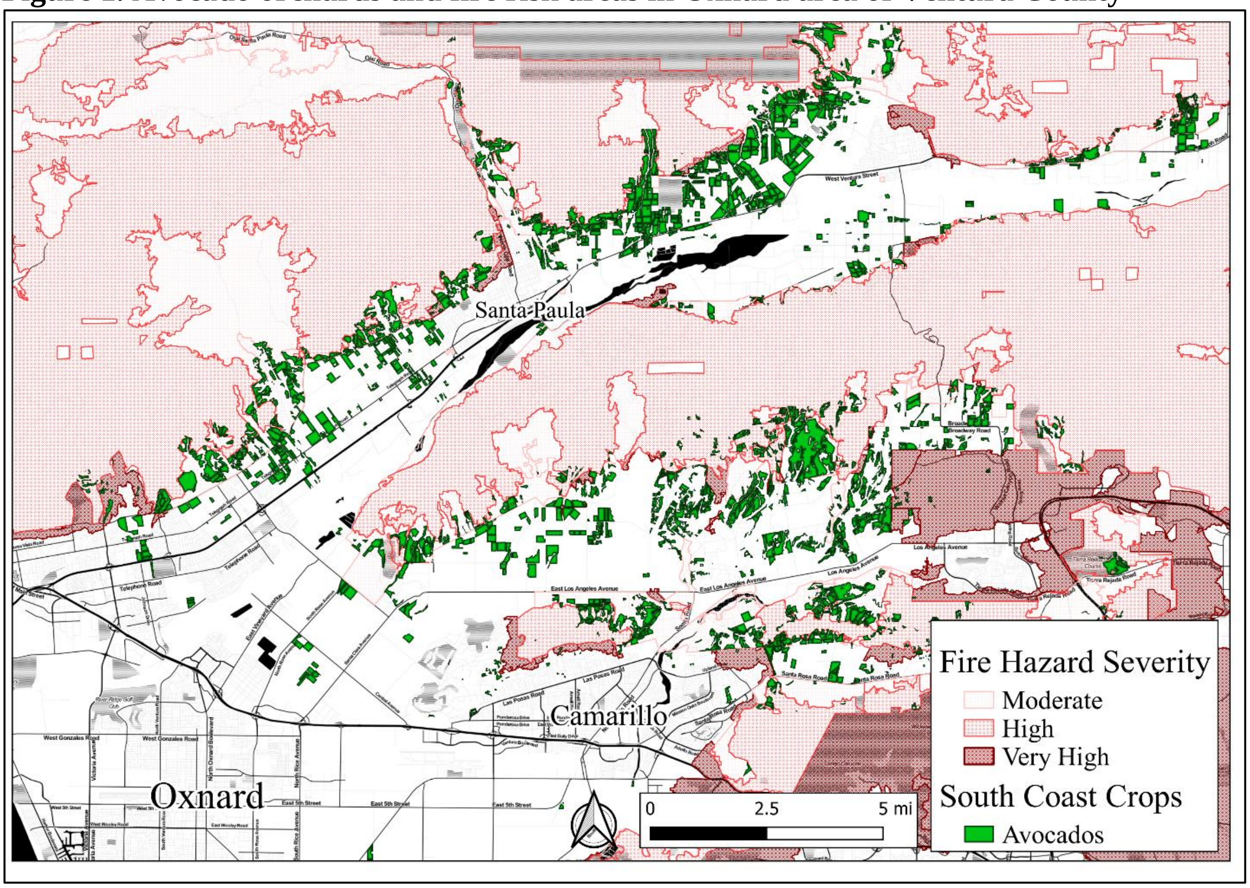
Table 3. Published costs of constructing a firebreak

Source	Year	Location	Cost ($/acre)	Notes
USDA NRCS	2014	Missouri	$1,864 - $5,418	Medium equipment, slope>15%, 1,000 foot firebreak; higher cost includes erosion control
Loomis et al. (2016)	2016	California	$286 - $455	Cost increases for lands in a metropolitan county and at wildland-urban interface
Calkin and Gebert (2006)	2006	Western U.S.	$213	Average cost per acre for mechanical treatment

A review of several local fire management plans was conducted and combined with a geospatial analysis of fire risk and existing orchard lands. The review included Ventura County and six fire plans in San Diego County. The Montecito Community Wildfire Protection Plan Amendment (2019) includes specific reference to including avocados in firebreak plans, noting “where possible and appropriate, implement a shaded fuel break concept along the northern portion of the District using native shrubs and/or introducing oak trees or agricultural vegetation (citrus, avocado).” They note that shaded fuel breaks can reduce soil erosion, reduce potential for vegetative undergrowth, and break up fuel continuity, but also need to be managed for landscape and topography-specific factors (e.g., adjacent vegetation).

Land use and fire hazard maps for Ventura and San Diego County were compiled to evaluate the spatial distribution of existing orchards and fire risk areas. Avocado orchards are an important component of the wildland-urban interface. Figure 1 below illustrates avocado acreage in the Oxnard area of Ventura County and its proximity to Fire Hazard Sensitivity Zones and urban areas. Avocado orchards are located on sensitive hillside areas where they have two potential roles as firebreaks. The specific value of an avocado orchard in the Oxnard area depends on its value as a firebreak. As described earlier, a more active management strategy could consider incentivizing additional orchard development to provide additional firebreak benefits.

Figure 1. Avocado orchards and fire risk areas in Oxnard area of Ventura County



4. The Value of Carbon Sequestration

The value of carbon sequestration is an important nonmarket benefit attributed to California avocado orchards. A 2012 study prepared by researchers at UC Riverside identified the potential for carbon storage in California avocado orchards, and identified areas for future research (Jenerette 2012). A review of subsequent literature did not identify carbon analysis specific to avocado orchards in California, so this continues to be a recommended area for future work.

The current carbon market in California is young and evolving. Offset credits traded in the most recent carbon market for around $16.75/mt. If carbon offset credits are established for specific avocado farming practices, this could become an additional benefit that could be monetized by growers.

4.1 Valuation Methods

The value of carbon sequestration can be established using several approaches. In California, where a carbon market exists, the valuation method relies on establishing the quantity of carbon sequestered by an avocado orchard and the going market rate of carbon offset credits. There is currently no offset credit for avocado growers that can be quantified and sold in the market. There are currently two agricultural carbon offset activities listed on the California Air Resources Board (ARB) carbon market website: installation of a biogas control system for manure management on dairy cattle and swine farms and reductions in methane emissions from flooded rice fields. Adding avocado orchards as a carbon sink would allow this benefit to be monetized directly in the market.

The price of carbon credits depends on supply and demand. ARB reports prices that are joint between the California and Quebec carbon markets (joint auctions have been held since 2014). Carbon allowance prices were around $12.25/mt in 2014 and have increased to around $16.75/mt currently. Prices peaked around $17.80/mt in late 2019.

The quantity of carbon sequestered is typically established in a carbon Life Cycle Assessment (LCA). This is a method for assessing carbon associated with all the stages of the production cycle of a product (in this case, avocados). This can include evaluating all inputs purchased and outputs at each stage of production, and under alternative management practices. For example, orchard establishment would include an assessment of nursery stock, labor, and all equipment/implements. Production would include an assessment of all soil amendments and pest management practices. The net carbon footprint can be established at each point in the production process. This can provide insights into management practices that provide a net carbon benefit. Some examples from the current literature are presented below.

4.2 Values from the Literature

As described above, the California carbon offset market is young and evolving. Given the limited data on the market and carbon LCA for avocado orchards, a broader literature review was conducted to develop a range of potential carbon offset benefit values.

McPherson et al. (2016), using the iTree Street program, estimates the value of carbon dioxide sequestration to be about $1.21 per urban tree in California. The potential value for a specific acre of avocados in California depends on the planting density and other site-specific conditions. High-density planting methods can result in up to 400 trees per acre (10x10 foot blocks). Traditional orchards are typically planted at a density of 110 trees per acre. The resulting value would be between $130 and $485 per acre. In aggregate, Nowak & Greenfield (2018) estimates the value of carbon sequestration in California to be about $400 million per year.

Table 4. Example benefits of carbon sequestration

Source	Year	Location	Benefit ($/acre)	Notes
Nowak & Greenfield	2018	California	n/a	Aggregate benefits of over $400 million per year
McPherson et al.	2016	California	$130 - $485	Per acre benefit values vary based on planting density
CARB	2020	California	n/a	Current carbon offset market in California is around $16.75/mt

5. Trade Balance Considerations

The overall U.S. trade deficit in August 2020 was $67.1 billion, the highest deficit since 2006. Excluding services, the trade deficit was $83.9 billion, the highest ever recorded. Rapidly increasing per-capita avocado consumption coupled with steady production in California mean that avocados are a small contributor to the growing trade deficit. Any loss of avocado acreage in California is largely offset by increasing acreage in Mexico or South America. Programs and policies that could encourage California production would reduce the trade deficit for avocados specifically and provide a small reduction to the broader U.S. trade deficit.

As recently as 2001, U.S. avocado production accounted for most of U.S. consumption (USDA 2020). At that time, the average American consumed about two pounds of avocados per year. Since then, U.S. demand has quadrupled but supply from American producers has declined. By 2018, average avocado consumption was around 8 pounds per year. Around three-quarters (6 out of the 8 pounds consumed) are imported from Mexico, one-eighth (1 out of the 8 pounds) is grown in the U.S., and the remainder is imported from South America.

U.S. avocado production in 2018 was around 364 million pounds. Only a small fraction of U.S. avocados are exported. Imports accounted for almost 87 percent of fresh avocado utilization in

2018. Among major fruits this share was only exceeded by papayas, mangos, and bananas. Avocado product imports into the U.S. were worth $2.17 billion in 2018 (OEC 2020).

The U.S. has a limited ability to meet U.S. avocado demand due to limited land, water, and climate conditions. Unlike citrus, a subtropical fruit, avocados cannot stand temperatures below freezing. Production is limited to southern Florida, Hawaii, and Southern and the Central Coast of California where suitable land and water supply limit potential acreage. California accounts for all Hass variety production, which is around 95 percent of California's total volume. Mexico, Chile, and Peru imports are also Hass variety, which is the variety typically demanded by consumers. Total bearing acreage in the U.S. was about 53,000 in 2019 of which 47,300 were in California (CAC 2020) and about 5,000 acres were in Florida. Only 840 acres produced avocados in Hawaii in 2018-2019 (State of Hawaii 2020). There may be potential for expanded U.S. production there.

Rapidly increasing per-capita avocado consumption and steady production mean that avocados are a contributor to the growing trade deficit problem. However, the share of trade represented by avocados is a tiny fraction of the total. Due to climate, water, and land factors there is little potential for a made-in-the-USA policy to increase avocado production in the U.S. Still, it would be fair to claim that California avocados contribute to a reduced trade deficit. Any loss of avocado acreage in California is largely offset by increasing acreage in Mexico or South America.

6. The Value of Erosion Control

Erosion control on agricultural lands provides indirect "off-site" benefits to urban neighbors by providing soil stabilization that may otherwise not exist naturally. Such benefits include the prevention of sedimentation and siltation of reservoirs and rivers, mud and landslides, water pollution, landscape degradation and abandonment, and wildlife habitat loss, as well as an increase in soil water holding capacity. The most serious off-site erosion problems are typically caused by the accumulation of soil particles and agricultural chemicals in the water system, which may increase flood risk and the costs of water treatment in urban areas (Pimentel et al., 1995; Posthumus et al., 2013). Along the agricultural-urban border, avocado and citrus groves typically provide such benefits for nearby urban residents by intercepting rainfall at the tree canopy and forest floor, reducing stormwater run-off.

Local and state agencies in California often use mulching, netting, blankets, mats, and other expensive treatments to prevent soil erosion in areas that may be adversely impacted by erosion – e.g., steep slopes near parks, roadsides, and residential neighborhoods (see Figure 2). In some cases, where erosion is severe, agencies may construct detention ponds, costing upwards of $140,000 (Krieger 2001). Table 3 summarizes the reported average cost per-acre of common erosion control techniques used by the California Department of Transportation (Caltrans).

Table 3. Average cost per-acre of erosion control techniques used by Caltrans

Technique	Avg. Cost Per-Acre	Functional Longevity	Recommended Maximum Slope (H:V)*
Mulch	$20,000	< 3 years	<2:1
Compost	$15,000	-	<2:1
Import Soil	$30,000	-	<1.5:1
Netting	$45,000	3 years	2:1 to 1:1
Blanket	$20,000	1 year	2:1 to 1:1
Mat	$55,000 - $260,000	>3 years	2:1 to 1:1

* H:V measures slope as the ratio of horizontal to vertical change.
Source: Caltrans Erosion Control Toolbox, 2020. Cost estimates come from Cal Trans Contract Cost Data, 2020.

Erosion control has an up-front cost of between $15,000 and over $250,000 per acre, with additional annual operation and maintenance (O&M) costs. Agriculture can provide erosion control benefits at effectively zero public cost, since the costs of establishing and maintaining the orchard are internalized by the grower. The cost of erosion prevention measures and the cost of erosion-related public safety events are well known. The avoided cost approach is commonly used by economists to estimate the ecosystem service value of erosion control provided by agriculture.

The value of erosion control only applies to areas where there is a risk of erosion that would affect public safety and health and impose a cost on society. For example, silage production is not typically associated with erosion control benefits. This report focuses on the benefits provided by orchards, with particular emphasis on those orchards planted in erosion-prone areas. As such, the per acre ecosystem service values are reported in dollars per acre per year, but only apply to land in erosion-prone areas.

In San Diego and Riverside Counties, new avocado orchards can be established in areas with a moderate to steeply sloped hillside, which are at high risk for soil runoff and sedimentation. Increasing conversion to urban development forces growers to establish orchards in less-suitable areas. In erosion-prone areas growers will invest additional resources to prevent and control erosion risk. Prior to planting crushed brush is left on the ground surface to enhance organic residue, and during the first planting year additional erosion control methods are applied, including paving roads, installing drainage systems, seeding exposed areas of the ground, and applying mulch to the tree rows (Takele et al. 2011). Erosion control is performed for the rest of the orchard life, including cleaning drains and sand bagging. By planting and maintaining orchards growers indirectly save costs of alternative erosion control measures, such as those applied by Caltrans, which are typically financed by taxpayers.

6.1 Valuation Methods

Economic benefits of erosion control most commonly are quantified using the avoided cost approach. This technique quantifies the avoided costs that would have been incurred in the absence of those services, in this case, agricultural crop production in erosion-prone areas near the agricultural-urban border. Soil erosion prevention saves money otherwise spent on sediment removal from waterways and roads, the treatment of contaminated water runoff, flood regulation and damage repair, and the replacement of lost soil and nutrients. Alternatively, the control of soil erosion on farmland saves agencies the cost of developing erosion control systems, such as applying mulch, compost, nettings, blankets, or mats (Caltrans 2020). Relevant studies reviewed have applied the avoided cost approach to valuing soil erosion control in different regions of the United States. The estimated values therefore vary depending on factors including geography, urban density, and type of prevention method used. Relevant studies are summarized below.

6.2 Values from the Literature

A literature search was performed to identify the economic value of erosion control on agricultural lands near urban areas. Over 50 studies were reviewed. The most applicable studies were selected for measuring the value of erosion control in Southern California. Using the avoided cost method, previous studies have estimated erosion control benefits from trees, including maintenance of arable land and erosion/siltation prevention. Studies by Costanza, et al. (1997) and de Groot et al. (2002) report estimates for forested land, tropical regions and grass/rangelands ranging from $15.72 to $140.76 per acre. Additional studies by Krieger (2001) and Dwyer et al. (1992) find that soil erosion benefits amount to $2.75 per ton in Tennessee, $7.81 million annually in Oregon's Willamette Valley, and $0.31 per tree annually in Tucson, Arizona.

The study by McPherson et al. (2000) was identified as the most applicable for valuing erosion control benefits on agricultural land in California. The report explains that water runoff is a major pollution source in urban areas, and that trees help improve soil capacity by absorbing rainfall and reducing overland flow – a byproduct of reduced soil erosion. McPherson et al. (2000) estimate the implied value of rainfall intercepted by a typical residential tree by considering current expenditures for flood control and urban storm water quality programs in the Los Angeles region. Specifically, using estimates of annual rainfall interception per tree and cost per gallon of storm water treatment and flood control efforts (during 25-year flood events) in the region, they estimate that erosion control benefits per residential tree in Southern California coastal communities ranges from $4.88 to $6.72 per year, depending on tree size. Table 4 summarizes the results of their study for the annual value of erosion control provided by small, medium, and large sized residential trees in the Los Angeles region. Assuming transferability of these results to agricultural lands in Southern California, and given that avocado trees are typically planted at 145 per acre, estimates for the economic value of erosion control on agricultural lands will range from $709 to $975 per acre.

Table 4. Economic value of erosion control provided by trees in Los Angeles region

Tree Size	Rainfall Interception	Max. Height/Spread	Annual Value*
Small	1,302 gal/yr	23/28 ft	$4.88
Medium	1,525 gal/yr	24/28 ft	$5.88
Large	1,799 gal/yr	36/39 ft	$6.72

* Benefits associated with flood control and urban storm water quality. Values reported in 2020 dollars.
Source: McPherson et al., 2000

The McPherson et al. study focuses on coastal communities in Southern California. However, there are reasons to believe that such estimates are likely to be an upper bound on the true economic value of erosion control on agricultural lands in the areas of interest. In particular, McPherson et al. focus on the value of residential trees rather than agricultural trees and thus the benefits to flood control and storm water quality may be smaller on a per tree basis on agricultural lands that are farther away from urban centers. Further, they calculate the annual value of flood control per gallon of water intercepted based on avoided costs with respect to a 25-year flood event in the region, which is likely to bias their estimates upwards as compared to the value in a typical year. Therefore, it is not entirely possible to determine, without additional data and analysis, a precise economic value of erosion control on agricultural lands in specific areas in Southern California.

Studies from more recent years find values in a similar range. McPherson et al. (2016) uses the iTree Street program to evaluate ecosystem services provided by urban trees in California. This study identifies rainfall interception as an important ecosystem service for soil erosion prevention, and estimates the value per tree per year of rainfall interception to be between $2.12 and $9.15 across the state, with an average of about $4.88 per tree per year. This study estimates the total benefit of residential trees for rainfall interception to be $8.87 million annually to Southern California communities, or about $3.21 per tree ($465 per acre assuming 145 trees per acre). This is significantly less than other states (e.g., $18 in Indiana and $31 in Missouri), the reasons being that average rainfall is so much lower across California, and that rainfall primarily occurs in the winter while deciduous trees are dormant (McPherson et al. 2016). Avocado trees are dense, evergreen trees, and therefore could be more valuable in intercepting rainfall, as increased tree leaf area is positively correlated with rainfall interception by the tree crown (Li et al. 2017).

7. The Value of Agricultural Open Space

Agricultural open space provides several non-market benefits (and costs) to society. The two most common benefits cited are associated with reduced urban sprawl and improved residential viewscapes. Negative amenities include noise, dust, and chemical application externalities. However, the literature is clear that there are positive effects on home values located in closer proximity to agricultural open space. Therefore, on average, the positive values of agricultural open space outweigh the negative amenity value.

Agricultural open space provides direct and indirect benefits to urban neighbors. Direct benefits may include providing growers with a more robust agricultural industry, including more readily available input and labor markets. Bordering urban neighborhoods may experience increased property values from proximity to agricultural open space (e.g., forests, pastures and grasslands), translating to increased property taxes for the county. Indirect benefits may include the preservation of land for agriculture to expand and respond to changing market conditions, preservation of rural character, and prevention of urban sprawl.

Residential home and land values near agricultural lands can be used to statistically infer the value of agricultural open space. Residential market prices may reflect the positive values of aesthetics, recreation, water supply, ecosystem service benefits, and prevention of noise and other effects of urban sprawl. In addition, prices may also reflect the negative values of noise pollution, odors, dust, and agricultural traffic congestion. Economists have measured the extent to which such amenities generated by agricultural farmlands (both positive and negative) impact residential property values. Several studies have indicated that forests (Tyrvainen & Miettinen 2000), pastures (Irwin 2002), and farms preserved by easements (Geoghegan 2003) can increase the value of nearby residential properties, while others have indicated that confined animal feeding operations and other intensive farming practices can decrease property values (Palmquist, Roka, Vukina 1997; Ready & Abdallah 2005). It is clear that orchards provide positive aesthetic benefits and none of the negative factors associated with animal operations.

Establishing the value of agricultural open space using residential home values may seem to be a counter-intuitive approach. Agricultural open space provides direct benefits to the county by reducing congestion and urban sprawl, which saves taxpayer expenditures on public services. In fact, the approach of estimating agricultural open space value using residential home sales captures all values associated with the “total” ecosystem service value of agricultural open space.

7.1 Valuation Methods

The value of agricultural open space is typically measured using hedonic pricing methods that quantify the relationship between residential property values (e.g., home sales prices) and a bundle of amenities generated by nearby agricultural lands. Because homeowners value the individual characteristics of their properties, including those related to nearby agricultural open space, market prices would typically reflect such values. Such analyses include home characteristics such as square-feet, number of bedrooms, and age of home, in addition to the proximity of the home to agricultural open space. The value of agricultural open space is then inferred by statistical analysis of the value of homes near an agricultural open space versus the value of similar homes further away from that space. In order to correctly value open space, the analysis must control for other factors that affect the price of a home. Economic studies have additionally shown that there is a difference in the valuation of permanent and temporary open space. Society generates a higher value from land that is zoned (or otherwise restricted) for permanent open space

7.2 Values from the Literature

A literature review was performed to identify the economic value of agricultural open space value in California. Most areas where avocados are produced are near high-valued residential development. Over 50 studies were reviewed to identify the most applicable studies.

The study by Kuminoff (2009) estimates a hedonic pricing model using home sales price data from San Joaquin County. He estimates, on average, that converting one acre of cropland into urban development within ¼ mile of the average home would reduce its market price by 2.2%. There is a small share (approximately 5%) of homes that do not benefit by being near productive land, however Kuminoff concludes that there is enough evidence that agricultural cropland generally provides positive value to nearby areas. Assuming transferability to Southern California, estimates for the economic value of an acre of agricultural cropland (that may otherwise be converted to urban development) are obtained by calculating 2.2% of the median home sales prices in selected Southern California counties (see Table 3). Using this approach the annualized value of an acre of agricultural cropland within ¼ mile of residential properties ranges from $492 per home in San Bernardino County to $1,144 per home in Orange County (see Table 3).

The value of agricultural open space is derived directly from the urban areas that benefit from the open space. With a less dense population the county has to spend less on transportation and other public infrastructure. The hedonic pricing approach implicitly assumes that the value of these benefits is reflected in home sale prices. A rich economic theory underlies this approach. Avoided cost valuation methods are also possible, but are typically not completed due to insufficient data.

Table 5. Economic value of an acre of agricultural cropland within ¼ mile of urban development

County	Median Sales Price	Price Increase if within 1/4 mile of Cropland	Annualized Value per Home*
Los Angeles	$678,000	$11,662	$948
Orange	$782,000	$14,072	$1,144
Riverside	$420,000	$7,156	$582
San Bernardino	$380,000	$6,048	$492
San Diego	$632,000	$11,156	$907
Ventura	$637,000	$12,072	$981

* Assumes benefits of open space received by homeowner as an annuity over 15 yrs with 3% discount rate.
Source: Zillow Home Value Index, October 2020; Kuminoff (2009).

The Kuminoff study uses data from San Joaquin County. It is important to note that cropland and the agriculture-urban border are different between San Joaquin and other parts of California. Southern California areas generally produce higher-value agricultural products, face different agricultural constraints, and have higher per-capita income, land, and real estate values. Therefore, the values estimated by Kuminoff may not be directly applicable to Southern California. Due to the density of population in most counties it is likely the Kuminoff estimates represent a lower-bound on the value of agricultural open space.

Hedonic price analyses completed since Kuminoff's 2009 study confirm the overall value of open space across different communities. Hiebert and Allen (2019) estimate a value increase of approximately 2.9% per square mile closer to the nearest agriculture in Greenville County, SC. Fan, Hansz, and Yang (2015) develops a spatial Durbin model (SDM) to estimate the Marginal Willingness To Pay (MWTP) for proximity to open space in the Fresno, CA metropolitan area. They estimate MWTP as high as $39.79 per meter, which would equate to just under $16,000 per square mile, or about 6.5% of mean home sales prices. This study, however, also identifies MWTPs much lower, particularly during "bust" housing markets, and does not include agricultural open space in its analysis, although Fresno is a very active agricultural region (Fan et al. 2015).

Additional data and analysis would be necessary to determine whether such differences may bias estimates up or down when extrapolating to Southern California. Although the two areas are subject to different county level policies, San Joaquin County represents the best available proxy for Southern California areas for which an existing study was available. The study by Kuminoff (2009) captures the important aspects of the value of agricultural open space and results show that proximity to cropland increases residential property values near the agricultural-urban border by approximately 2.2%.

Applying data from other regions in California and the U.S. to Southern California avocado producing regions would require some evaluation of individual and community preferences regarding proximity to agriculture. The Ventura County 2040 General Plan, adopted in 2020, identifies "Agricultural Greenbelts," which are agricultural lands which cannot be converted to urban land without voter approval. The Ventura County Greenbelt Program includes the Ventura-Santa Paula Greenbelt and Santa Paula-Fillmore Greenbelt (Ventura County 2020), protecting agricultural land and open space for residents in areas that are also major avocado producing regions. The General Plan also identifies the Save Open Space & Agricultural Resources (SOAR) initiative, signed initially in 1998 and renewed through 2050, adding further protections to agricultural open spaces for residents of Ventura County. The San Diego County General Plan (last amended in 2020) similarly identifies the preservation of farmland and open space in rural areas as benefitting all of San Diego County. The plan lists Agricultural Conservation as one of the County's Land Use goals, citing "farming and agriculture as beneficial resources that contribute to the County's rural character" (County of SD 2011).

8. The Value of Air Quality

Agricultural trees, vines, and plants provide indirect benefits via improved air quality in nearby urban areas. Trees and vegetation help improve air quality by directly removing pollutants from the air. All residents enjoy cleaner more breathable air, disease prevention (e.g., skin cancer, asthma, etc.), visibility improvements, and less damage to landscape materials and ecosystem processes. Orchards bordering urban communities provide such air quality benefits, but the value varies, depending on a city's pollution concentration, leaf-surface area (foliage density and cover), tree variety, age, and size among other factors.

Most established agricultural trees in Southern California tend to be in avocado and citrus groves. Other cropland may provide air quality benefits, but these are not typically quantified in existing economic analyses. Further, agricultural production generates air emissions through potentially the use of off-road vehicles, diesel pumps, and other machinery. Thus, the air quality benefits should be interpreted as gross benefits before including these negative effects produced by agriculture. The values presented in this report correspond to the air quality benefits generated by an acre of orchard, plated at 145 trees per acre.

8.1 Valuation Methods

The economic value of air quality improvements can be estimated using an avoided cost approach but is generally assessed using contingent valuation methods. Contingent valuation (CV) uses carefully structured surveys to elicit the value that consumers place on a particular non-market good. The primary objective of CV is to elicit the maximum willingness to pay by a group of representative beneficiaries for a specific level of improvement in a good or service that is not typically provided by the market (e.g., clean air). For example, a survey questionnaire might ask respondents to quantify the amount of money they are willing to pay in taxes or fees to achieve the benefits of improved air quality, resulting in health and environmental benefits. CV also includes so-called "stated preference" methods, which do not infer values based on choices made, but rather asks a person to directly reveal their values. Stated values elicited through a survey are likely to vary by location, demographic characteristics, socioeconomics, and other market conditions.

The CV approach requires construction of a careful survey that avoids survey-response bias. For example, it is known that respondents will typically overstate their total willingness to pay. In studies where respondents are asked to pay their stated value of the service immediately after the survey, many respondents will not be willing to part with the money. The survey is designed to control for this type of self-reporting bias.

8.2 Values from the Literature

A literature search was performed to quantify the value of air quality improvements provided by agricultural lands to nearby urban areas. The literature reviewed focused on reductions in nitrogen dioxide (NO_2), carbon monoxide (CO), ozone (O_3), particulate matter less than 10 microns (PM_{10}), and sulfur dioxide (SO_2).

Studies by McPherson et al. (1999) and Scott et al. (1998) use the CV method to estimate air quality benefits from well-established urban trees, and find values ranging from $7.50 to $49.29 per tree. Other studies have reported total benefits in urban areas ranging from $134,230 to $14.8 million annually (American Forests 2003; Nowak et al. 2007). Applying the avoided cost method, a study by de Groot in 2002, reports that air quality benefits from well-established trees range from $50 to $125 per acre. Although such estimates provide insight into the per acre benefits of air quality improvements provided by agricultural croplands, they do not represent the geographical, social, or climatic features of Southern California. Further, these studies typically do not define how such air quality improvements are explicitly broken down into the specific pollutants being offset – such as nitrogen dioxide (NO_2), carbon monoxide (CO), ozone (O_3), particulate matter less than 10 microns (PM_{10}), and sulfur dioxide (SO_2).

A study by the United States Department of Agriculture (USDA) Forest Service in 2001 estimates that the value of air pollution uptake per tree in the San Joaquin Valley was $63.85. The study, based on the McPherson et al. (1999) data, examines annual benefits of avoided emissions plus uptake of NO_2, PM_{10}, and Volatile Organic Compounds (VOC), in the San Joaquin Valley. The benefits are determined by quantifying the pollutant deposition into the air and then calculating the amount of pollutant interception for an average tree, based on a 9-month absorption period. Hourly meteorological data were used for wind speed, solar radiation and precipitation, in conjunction with hourly concentrations for NO_2, PM_{10}, and VOCs within Modesto and Manteca areas. Using local market emission reduction credit prices with average emission uptake by tree and average pollution emission rates, the study estimates an uptake benefit of $63.85 for a large tree in the San Joaquin Valley.

A subsequent report by the same agency in 2011 quantified various ecosystem services provided by Los Angeles' urban forest using the Urban Forest Effects Model (UFORE) model that measures hourly air pollution and meteorological data on randomly selected plots to quantify forest structures and benefits (Nowak 2011). The report uses the UFORE model in combination with field data for the year 2000. The report estimates that trees remove 1,976 tons of air pollution per year, valued at $168.1 million, based on national median externality costs associated with pollutants. Specific pollutants quantified included CO, NO_2, O_3, PM_{10}, and SO_2. The report estimates, on average, that one tree within urban Los Angeles removes $57.48 worth of pollution annually – a value only slightly lower than the 2001 study in the San Joaquin Valley.

Assuming transferability to Southern California, where avocado trees are typically planted at 145 per acre, the total air quality value per acre can be estimated. Since the values in the studies correspond to an urban tree which is typically larger than an average tree on an orchard, the values are scaled by a factor of 10. Therefore, the estimates for the economic value of air quality improvements from agricultural cropland near the urban-agricultural border amount to $830 – $1,810 per acre per year.

The 2011 study reflects conditions in urban Los Angeles. Because the study focuses on urban rather than agricultural trees, the true values for air quality improvements from agricultural cropland may differ depending on tree species and size, type of pollutant, and proximity to the urban-agricultural border. Pollutants in urban Los Angeles are generally higher than other parts of the state, so the value of air quality improvements reported in the 2011 USDA study is likely to be an upper bound on the true value in other areas outside of urban Los Angeles.

Table 6. Economic value of air quality improvements provided by trees in urban Los Angeles

Unit	Pollution Removal	Annual Value*
City	1,976[a]	$16,775,761
Per Acre	13.1[b]	$830 - $1,810

* Benefits associated with annual uptake of CO, NO_2, O_3, PM_{10}, and SO_2. Values reported in 2020 dollars.
Source: USDA Forest Service, 2011
[a] Tons per year
[b] Pounds per year

More recent studies show air quality benefit values in a similar range. Nowak et al. (2014) looks at air pollution removal by forests by state across the nation using the EPA's BenMAP model. In California, they estimate the value of air pollution removal by forests in urban areas to be $839 per acre. This is assuming average tree cover of 36.1% for forests in California. This study acknowledges that BenMAP estimates for the value of air pollution removal can be relatively low, pointing out that using European air pollution cost factors would increase these estimates about thirteen-fold. McPherson et al. (2016), using the iTree Street program, estimates annual air pollutant uptake to be about $8.94 per tree in Southern California communities. At 145 trees per acre, this would equate to $1,296 per acre per year, assuming acres near an urban area.

9. Summary

This report presented the results of a literature review of the value of erosion control, open space, and air quality ecosystem services provided by agriculture. The findings of the literature review can be summarized as follows:

- Orchards located near high-risk fire areas can provide firebreak benefits valued at $200 to $2,000 per acre in capital costs alone. Additional operating and maintenance costs would increase this estimated benefit value.
- Avocado orchards have the potential to provide carbon sequestration with a non-market gross value of $130-$485 per acre per year.
- The U.S. runs a trade deficit for avocados. Policies that would encourage U.S. production of avocados would reduce this trade deficit.
- An acre (or portion thereof) of orchard in an area affected by erosion could provide a non-market value of $465–$990 per acre per year.
- An acre (or portion thereof) of agricultural cropland within ¼ mile of residential housing could provide an open space non-market gross value of $490–$1,100 per acre per year per home.
- An orchard could generate an air quality non-market gross value of $830–$1,810 per acre per year.

ERA has not performed a primary analysis of ecosystem service values. Rather, ERA has reviewed academic and governmental studies that have valued similar ecosystem services in other areas to provide the CAC with a range of estimates for those values in question. The estimates presented in this memorandum have been taken from studies that best represent Southern California. Since this approach relies on previously-completed studies undertaken elsewhere, it is important to note that the range of values provided may not directly represent the situation in the Southern California area.

This study considers the certain nonmarket benefits provided by avocado land without quantification of the benefits provided by an alternative land use or the taxes and fees provided by that alternative land use that may be used to compensate for the lost nonmarket benefits. Avocado orchards may provide benefits in the form of open space, air quality, reduced erosion, fire protection and stormwater infiltration, but alternative land uses in some areas might provide some of these benefits as well. A recommended extension of this initial analysis is to develop a benefit-transfer assessment that would determine location-specific nonmarket benefit values attributable to U.S. avocados. This would be used to support public policy and programs that could incentivize avocado production in targeted areas for the joint benefit of producers and the local economy.

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