Could Recycled Urban Wastewater Provide Irrigation for Agriculture? The Case of the Escondido Region of California

Ami Reznik and Ariel Dinar

Reuse of treated urban wastewater for beneficial purposes can mitigate water scarcity. However, its costs and benefits are uncertain. We examine reuse feasibility through a regional modeling framework in the Escondido region of California. Optimal results pertaining to avocado production in the region suggest significant reduction in cultivated area and preference of potable water over treated wastewater. However, supportive policies aimed at sustaining agricultural activity in the region, such as subsidizing high-quality treated wastewater used for irrigation, could be socially cost-effective.

Wastewater treatment and its safe disposal are necessary requirements for urban centers to prevent possible environmental damages and health risks. The costs associated with disposal of treated or untreated wastewater are predicted to increase in the future due to population growth trends and climate uncertainty. The reuse of treated wastewater for agricultural irrigation, as a strategy for disposal, can be beneficial to society and at the same time mitigate water scarcity. It is for these reasons that reuse is increasing globally, with regions around the world still discharging both treated and untreated (mainly in developing countries) wastewater to natural bodies of water.

The same trends also emerged in California, where reuse of treated wastewater for different purposes has increased from 175,500 acre-feet (AF) in 1970 to 714,000 AF in 2015. Irrigated agriculture however, used a decreasing share of these volumes in the last two decades. It is also reported that 417 billion gallons (nearly 1,128,000 AF) of good-quality, treated municipal wastewater were discharged in 2015 directly into California coastal waters. Growth of urban centers in proximity to irrigated agricultural regions increases the potential for reuse of treated wastewater.

We evaluate whether or not reuse of treated wastewater in irrigated agriculture is sustainable and economically efficient. We developed a regional modeling framework that accounts for the interaction and interdependencies among producers and consumers of treated wastewater, and the environment. The model was applied to the Escondido region in Southern California, and examined the conditions under which reuse is a feasible and sustainable alternative. The Escondido region resembles other regions along the California coast both in terms of physical and climatic conditions, and in terms of the high-value agricultural production. Thus, extrapolation of the analysis to other regions would allow the assessment of alternative water supply futures under climate and population changes.

The Escondido Region and Its Water Challenges

The City of Escondido is located in San Diego County in Southern California. The city currently supplies water to approximately 26,000 residential, commercial, and agricultural customers, using surface water from both imported (approximately 80%) and local sources. Due to rapid development and a growing population, water demands in the service area of the city have been growing steadily. At the same time, uncertainty of water supply availability is also growing, and the city's system infrastructural capacity is becoming a binding constraint.

Wastewater quantity, quality, and disposal locations are regulated by the state. A permit is required to treat the city's sewage and dispose the effluents into the ocean, which is currently achieved using an ocean outfall system. According to the city projections, the range of wastewater generation in the future could be extended to the point where the existing discharge infrastructure and treatment capacity would no longer suffice in handling the volume that needs treatment and discharge.

These considerations have led Escondido to engage in several long-term planning efforts. One prominent component of the plan is the city's treated wastewater recycling activity. Currently, only a fraction of the flow of sewage to Hale Avenue Resource Recovery Facility (HARRF)—the city's wastewater treatment facility, is reused for beneficial purposes. Expected insufficient capacity to meet state regulations for treated wastewater discharge to ocean outlets has created strong incentives to allocate that water locally for irrigation, thus avoiding significant expenses associated with the expansion of the ocean discharge capacity.

A possible recipient is avocado production, which is the main agricultural activity in this region. Recent droughts in California have highlighted the unfavorable conditions that agriculture in this region faces. In the absence of alternative water sources to irrigate their groves, growers have to pay significantly higher rates for potable water supplied by the city. In order to maintain production under such conditions, growers stump trees on significant acreage, drill deep wells to access saline water, and use expensive mobile desalters to avoid salinity damages.

Given these conditions and considerations, the city identified several

Table 1. Escondido's Water System Parameters

Component Description	Existing Capacity (AFY)	O&M Costs ($ per AF)	Capital Costs, Amortized Values ($ per AF)
Potable Water Supply	Bounded by Water Availability	1,250	0
Wastewater Collection	Not constrained	1,450	0
Treated Wastewater Conveyance to Agriculture	0	43.99	907
Desalination of Treated Wastewater for Agriculture	0	484.5	1,217
Desalination and Conveyance of Treated Wastewater to Augment Regional Supply	0	798.93	2,120
Wastewater Safe Disposal	24,000	29	990

Sources: Reports prepared by and for the City of Escondido for the years 2012, 2014, 2017 (available by the authors upon request).

potential solutions for treated wastewater allocation. The first, which is referred to as Non-Potable Reuse for Agriculture (NPR/Ag), develops a supply system to allocate recycled wastewater to the city's existing potable water consumers, specifically avocado growers. This system also includes the option to desalinate the effluents prior to its use in agriculture. The second option, named Indirect Potable Reuse (IPR), develops a separate new system to desalinate treated wastewater and convey that water to augment the city surface water supplies through storage in Lake Dixon—one of 11 reservoirs owned and operated by the city.

Regional Water and Treated Wastewater Allocation

We developed a regional model of a general setting that is comprised of a city that needs to treat and dispose of its wastewater, an agricultural sector, and the environment. In our model, environment refers to any receiving body of water that is susceptible to pollution by unpermitted discharge of the treated effluents. Alternatively, treated wastewater can either be discharged to a safe location (for example, a remote dry-bed river or the ocean), adhering to regulation and preventing environmental damage, or be reused for beneficial purposes within the region, specifically in irrigated agriculture.

The Model

The model finds an optimal regional plan of water resources allocation and infrastructure development that maximizes net benefits (or economic welfare) of all water consumers in the region, subject to several technical, hydrological, and regulatory constraints. These net benefits are defined as the total economic value of water for city inhabitants and agricultural revenue from crop output sales, minus operating and maintenance costs of the entire water system, the amortized costs of investments in infrastructure development, and monetary penalties for unpermitted discharge of treated wastewater to the environment. The model incorporates farmers' heterogeneity, and includes uncertainty in key variables of both farm-level and regional decision-making processes. Therefore, it captures the ability of the agricultural sector to sustain changing conditions in terms of available water sources and their quality. The model was adjusted and applied to local conditions in the Escondido region.

Data and Calibration

We collected data from public records and stakeholders in the region and we adapted some of the components of the analytical framework to the available data. Water supply to Escondido is provided mainly from imported surface sources. Total water supply ranges between 20,000–28,000 AF per year (AFY). Water availability to the region is variable and uncertain. Therefore, we assign a discrete probability for high- and low-water availability events.

The existing and planned water and wastewater systems in the region are represented in the model by infrastructural capacities, capital costs, and operation and maintenance (O&M) costs (Table 1). For capital costs, we use amortized values of predicted investments needed for development of alternative infrastructural components of the water system. The cost of expanding the capacity of the treatment plant is $120 per AF.

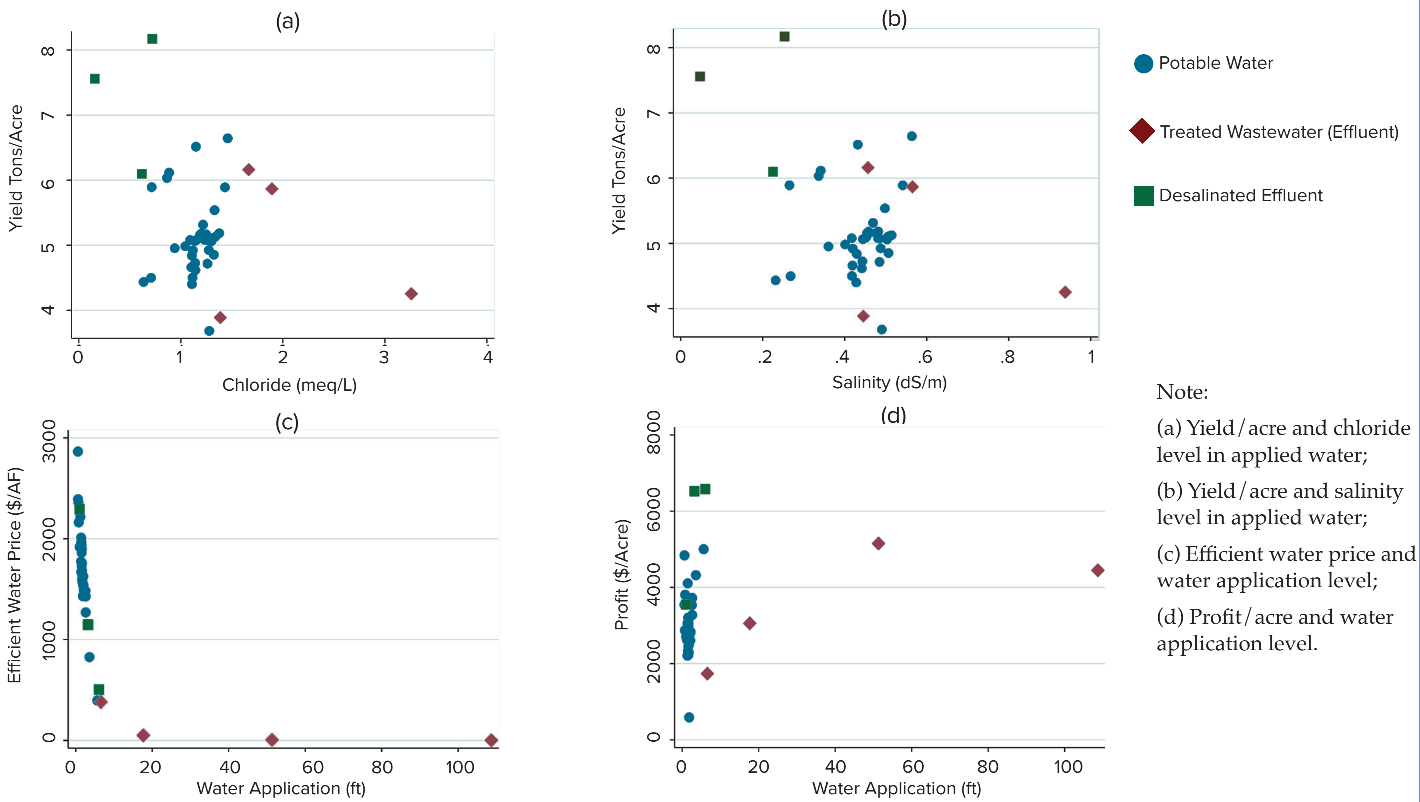
Differences in agricultural productivity and costs of avocado production in the region are captured in the model through non-linear functions that translate the use of land and water inputs to profits at the individual farm-grove level. The calibration process of these functions required high-resolution analysis of soil structure and weather in the region. In order to calibrate the parameters in these functions, we collected micro-data from individual avocado growers in the region. The growers surveyed and represented in the model are the only group of existing agricultural water consumers that will be connected (in the short-term) to the new treated wastewater supply system.

The model included distributions of avocado prices and regional precipitation, based on historical data. Salinity and chlorides distributions were measured in terms of high and low concentrations in each water source.

Results and Discussion

Our base scenario is constructed to best represent the prevailing conditions in the Escondido region as described in the previous sections. In this scenario, the ocean outlet, and unpermitted discharge to the environment are the only existing alternatives for treated

Figure 1. Tradeoffs in Agricultural Activity Indicators, by Type of Water Allocated for Irrigation



Note:

(a) Yield/acre and chloride level in applied water;

(b) Yield/acre and salinity level in applied water;

(c) Efficient water price and water application level;

(d) Profit/acre and water application level.

wastewater disposal. An optimal decision then must be made with respect to the construction of the other alternatives for treated wastewater discharge, and the allocation of all water resources available.

In terms of water quantities, results of the optimal plan suggest to discharge nearly 75% of the treated wastewater to the ocean, to divert nearly 15% to Lake Dixon to augment regional potable water supply, discharging the remaining share into the environment (with penalty). The total volume of wastewater treated and allocated is about 13,700 AFY. Consequently, the agricultural sector in the region relies exclusively on potable water from the city. The volume of potable water diverted to avocado production is nearly 250 AFY, which is only a quarter of the actual water used by growers in our survey. Total fresh water use in the region is about 16,600 AFY, such that most of the water is consumed in the urban sector.

The implications to the agricultural sector are profound. According to the base scenario results, the land area cultivated by growers should shrink to less than half of the existing enterprise. Water use for that reduced farm acreage is also considerably lower than its observed level. Yield per cultivated acre remains mostly unchanged, and this is mainly due to higher quality of water allocated to agriculture. The efficient economic price of water calculated based on these outcomes is $1,500 per AF, and is higher by 40% than the actual potable water price paid by farmers in the region.

Sensitivity Analysis

According to a sensitivity analysis we performed (not presented), the results of the base scenario remain robust to changes in assumptions and parameters of several key model components. These changes include distributional assumptions of regional water availability,, recalibration of parameters determining agricultural profitability, sensitivity of urban water consumption to prices, and regulatory constraints pertaining to water quantities diverted from the IPR project that are available for regional use following retention and dilution.

The analysis also revealed that uncertainty, specifically regarding water quality and its variation, and the magnitude of penalties for unpermitted discharge of treated effluents to the environment, are important drivers of the optimal plan. Irrigation of avocado groves with treated wastewater emerges as an optimal strategy in several scenarios included in our analysis. In these cases, results suggest that there are significant tradeoffs in terms of water quantity and its quality, yield and profitability, and efficient water prices when substituting potable water with treated wastewater. These tradeoffs are depicted in Figure 1, presenting all model runs used in the analysis, and dividing them according to the primary water source allocated to agricultural irrigation. Tradeoffs are nonlinear and indicate a reduction in yields as chlorides (panel a) and salinity (panel b) of the irrigation water increase, value of water (panel c) declining as quantity applied increases, and profit increasing in a decreasing rate as quantity of water applied increases. Rate of increase or decrease depends on the type of water (potable, treated, desalinated).

We also performed simulations of future conditions in the region, assuming higher urban demand for water. Results suggest that the impacts on agricultural activity described earlier might become exacerbated in the future, threatening the sustainability of the avocado industry in the Escondido region.

Supportive Agricultural Policies

Considering the profound impacts on agricultural activity and the strong tradeoffs to which we referred, led us to examine the cost (loss of regional economic welfare) of supportive policies for the avocado industry. For that purpose, we designed several scenarios that differ in the water sources agriculture is allowed to use, and in the types of supportive policies. Results from the scenarios differ substantially in terms of infrastructure development and allocation of water from the various sources. However, implementation of these policies amounts to nearly $2 million. In relative terms, this figure is only 1.3% of the annual expenditures of the Water and Wastewater Utilities Department of Escondido. It is implied that maintaining agricultural activity in the region at its current size is warranted if this level of welfare loss is surpassed by the indirect added value from agriculture to the region (which we do not quantify in our analysis).

Such indirect benefits could be significant. They include job creation in avocado operations and related services, sales taxes to the City of Escondido, economic multiplier effects of avocado operations through agricultural service businesses flowing through the Escondido economy, and carbon sequestration services (by 2030, the County of San Diego aims to plant 49,000 trees and an additional 70,000 trees between 2031–2050. Around 110 trees grow on an acre of avocados).

Concluding Remarks

Our analysis of the Escondido region in Southern California reveals that existing local conditions generally do not encourage reuse of treated wastewater in agriculture. Instead, our results suggest that safely discharging most of the effluent to the ocean, using existing infrastructure and augmenting regional surface water supplies with the remaining portion of wastewater after desalination is, in most cases, the preferred strategy. In addition, we find that uncertainty, specifically with respect to water quality and its variation, as well as imposed regulatory constraints, are important drivers of this outcome.

The agricultural sector in this region is limited in adaptation capacity, and therefore its sustainability is highly susceptible to changes in exogenous conditions. We find that supportive policies that could be crucial for the survival of the agricultural sector in the region are socially inexpensive. Therefore, implementing such policies, through capacity development and allocation of treated wastewater directly as well as after desalination, keeping agricultural water prices low and their quality high, would be warranted if benefits accrued in the region due to preservation of the agricultural sector surpass $2 million.

Our empirical analysis of Escondido is tailored to the specific conditions in this region. Such conditions include the lack of inter-temporal groundwater storage, altitude differences between storage reservoirs for surface water and planned facilities for treated wastewater supply, and the distance to safe disposal of treated wastewater in the ocean. Applying the regional framework presented herein to other regions across California and across the world would be a useful extension of our work.

Suggested Citation:

Reznik, Ami, and Ariel Dinar. "Could Recycled Urban Wastewater Provide Irrigation for Agriculture? The Case of the Escondido Region of California." *ARE Update* 23(4) (2020): 9–12. UC Giannini Foundation of Agricultural Economics.

Authors' Bios

Ami Reznik is a postdoctoral research scholar in the Department of Environmental Economics and Management at the Hebrew University of Jerusalem, and a former postdoctoral research scholar in the School of Public Policy, UC Riverside. Ariel Dinar is a Distinguished Professor in the School of Public Policy, UC Riverside, who can be contacted at adinar@ucr.edu.

For additional information, the authors recommend:

Heal the Ocean (Project Manager: James Hawkins; Research Assistants: Corey Radis, Alex Bennett), 2018. "Inventory of Municipal Wastewater Discharges to California Coastal Waters."

Hernandez-Sancho, F., Lamizana-Diallo, B., Mateo-Sagasta, J., and Qadeer, M. 2015. "Economic Valuation of Wastewater –The Cost of Action and the Cost of No Action." Nairobi: United Nations Environment Programme.

Reznik, A., Dinar, A., and Hernández-Sancho, F. 2019. " Treated Wastewater Reuse: An Efficient and Sustainable Solution for Water Resource Scarcity." *Environmental and Resource Economics* 74(4):1647-1685.

Acknowledgements: The authors acknowledge the support during data collection and analysis by officers of the City of Escondido Water Department, the San Diego County Farm Bureau, and the Escondido Growers for Agricultural Preservation (EGAP). The project leading to this article was partially funded by the Giannini Foundation mini-grant program.