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Projecting the Provision and Value of Water from National Forests in Southern California under Ecological Change

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Section 1: Introduction

Access to water is essential to economic growth, human well-being, and the health of our ecosystems. Growing populations, urban uses, demands for agricultural commodities and recreation uses, coupled with the predicted effect of climate change will exacerbate water scarcity, in particular in arid and semi-arid areas around the world. Addressing this challenge will require understanding ecosystems' water provisioning functions and value. While engineers and hydrologists can help quantify these relationships, economists can help value water provisioning and water purification services to inform the debate over how to protect and sustainably manage these resources. The economic value of these ecosystem services is rarely assessed by natural resource managers, or considered in planning and resource management decisions, despite these services being valuable to users and non-users. Indeed, decision makers often assume an implicit value of zero for these ecosystem services, and thus fail to quantify their value in terms of their opportunity costs.

In California, the most recent drought from 2012-2017 remains in the public memory, with climate-related precipitation issues continuing to be an ongoing concern for policy makers. Global climate models predict that most areas with Mediterranean-type climates will become drier (Polade et al., 2017). Correspondingly, climate change is expected to affect precipitation patterns in California (Cvijanovic et al., 2017). Although the most recent Coupled Model Intercomparison Project Phase 5 (CMIP5, Meehl et al., 2005) models indicate that precipitation is expected to increase during the winter months in California (Neelin et al., 2013), in southern California there is uncertainty (Polade et al., 2017). This uncertainty is not surprising as the high seasonal and interannual spatial and temporal variability of a Mediterranean climate make it difficult to model (Rodeghiero et al., 2011). Given lingering drought concerns and uncertainty with respect to precipitation forecast, these water issues are being translated into political initiatives in California, as evidenced by two bond issues relating to water on the 2018 ballot totalling over $13 billion; California voters previously approved a $7.5 billion water bond in 2014.

An examination of the environmental benefits generated by national forests through the framework of ecosystem services facilitates identification of how changes in these forest ecosystems affect human well-being; moreover, such an investigation can provide insight in a form that decision-makers can weigh alongside other relevant factors. The United Nations-initiated Millennium Ecosystem Assessment (MA) assessed the consequences of ecosystem change for human populations by focusing on the links between ecosystems and human well-being and, in particular, on ecosystem services. The MA defines ecosystem services as "…the benefits people obtain from ecosystems [including] *provisioning services* such as food, water, timber, and fibre; *regulating services* that affect climate, floods, disease, wastes, and water quality; *cultural services* that provide recreational, aesthetic, and spiritual benefits; and *supporting services* such as soil formation, photosynthesis, and nutrient cycling" (Millenium Ecosystem Assessment, 2005).[1]

In spite of technological buffers that partially protect humans from adverse effects of environmental changes, urban populations near national forests often depend upon the flow of ecosystem services from them. National forests were established primarily to provide water provisioning services to nearby residents. In fact, public concern about adequate supplies of clean water resulted in the establishment of federally protected forest reserves in 1891 (USDA Forest Service, 2000). The vast majority of freshwater in the United States originates from forests – about 80 percent – out of which about 14 percent originates from national forests (USDA Forest Service, 2000). About two-thirds of the country's runoff comes from national forests;[2] in the west, national forests provide one third (33 per cent) of freshwater runoff since they encompass the headwaters of major rivers and mountain ranges.

National forest staff and decision makers can improve the sustainable management of their water resources by accounting for its economic value as this will ensure that stakeholder preferences are reflected in budget and resource allocation priorities. United States Forest Service (USFS) land managers can use these monetized values as they make trade-offs between options to allocate resources that can benefit forest users as well as downstream stakeholders. As climate change alters ecosystem functions, the quantity of water

[1] Italics added.
[2] This figure excludes Alaska.

provisioning ecosystem services provided by forests and shrubs will also change, as will their values; these changes in value in turn affect peoples' welfare and their communities.

Despite growing interest in this area, there is little understanding of how land and resource managers of public lands can better evaluate potential trade-offs when making resource management and planning decisions that account for changes in ecosystem service values in the face of climate change. This paper addresses this information gap. The economic value of water provisioning ecosystem service from four national forests in southern California are investigated. These forests – Los Padres, the Angeles, San Bernardino, and the Cleveland National Forests – are primarily dominated by shrubland (chaparral and coast sage scrub), hardwood forests (oak woodland), conifer forests and glasslands.

The purpose of this analysis is to investigate the value of raw surface water from large public lands and how this value will change in the future as climate changes. Specifically, insight is sought into how the economic value of water provisioning ecosystem service from four national forests in southern California will change over time. Monetized values under a business as usual scenario are estimated under three possible future climate realizations, and accounting for possible behavioral changes due to changes in water supply.

This paper seeks to understand the economic value of surface water ecosystem services by 1) projecting the volume of surface water runoff from four national forests in southern California – Los Padres, Angeles, San Bernardino, and Cleveland – under future climate scenarios at mid- and end-of-century, and 2) estimating the economic value of surface water provided under current and future scenarios. We generate estimates by coupling projections of surface water runoff from a dynamic global vegetation model with a range of estimates of the marginal value of surface water from the literature. Specifically, the research question addressed in this study is how will the economic value of water provisioning service from the four national forests change with climate change at mid- and end-of-century under three different climate scenarios?

Section 2: Importance of Ecosystem Service Valuation for Water in the National Forests

Valuing water resources in policy decisions is fraught with many challenges. Limited transparency in pricing, convoluted water markets, and political sensitivities are compounded by changes in climate, and precipitation patterns. Nevertheless, the current value of the water provisioning service from national forests must be estimated to effectively manage the resource in the face of changing biophysical processes.

National forests connect and encompass watersheds as well as terrestrial and coastal ecosystems, producing a variety of valuable environmental services, including the supply and purification of fresh water. There are 81 National Forests in the western U.S., collectively occupying 573 thousand km^2 (57,300,000 ha). These National Forests provide an annual average water yield of 230 billion m^3 (Brown et al., 2016), 49 percent of the mean annual water supply in the west.[3]

The four national forests in southern California – Los Padres, the Angeles, San Bernardino and Cleveland – cover 14,335 km^2 and generate a mean annual water supply volume of 2.05 billion m^3 – amidst a population of almost 23 million people (U.S. Census, 2010). These forests are largely semi-arid and Mediterranean ecosystems. Wildfires and increasing drought in the area are further stressors on the ability of the national forests to provide water to the counties and municipalities. The national forests being studied are naturally subject to cycles of wildfire, the frequency and magnitude of which are exacerbated by the historical planting of non-native species. Of the 20 largest fires recorded in California, 11 – or 55 percent – have occurred within the counties that house one of the four national forests (Calfire, 2015).

Given these stressors and climate change challenges, it is imperative to forecast how the economic value of water from these forests will change due to climate change; moreover, fires and changing precipitation patterns can result in increased damages and reduction in water availability which can decrease the well-being of households in this heavily populated region.

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[3] The included states are: Arizona, California, Colorado, Idaho, Montana, New Mexico, Nevada, Utah, Washington and Wyoming.

Section 3: Methods

Economic values are estimated in a two stage process. The quantity of water from the national forests is estimated spatially via a dynamic vegetation model which is then coupled with economic water values. An advantage of coupling the biophysical model outputs with economic water values is that it can identify spatial heterogeneity in the provision and value of surface water as an ecosystem service. Model projections that vary across space, coupled with economic water value information, may allow policy makers to weigh trade-offs associated with site-specific forest management actions.

The volume of surface water runoff – average annual volume at baseline period (1970-1999), mid-century (2035-2064), and end-of-century (2070-2099) – is estimated using the MC2 dynamic global vegetation model (USFS, 2001) calibrated to southern California using multiple observation datasets. MC2 model simulates vegetation response to climate change over time, incorporating ecosystem carbon and water cycling, vegetation biogeography, and wildfire effects. Simulations are driven by downscaled climate projections based on three general circulation models (GCMs) simulating representative concentration pathway 8.5 (a "business as usual" emissions scenario; van Vuuren et al. 2011). The three GCMs span a range of future climate characteristics, from relatively hot and dry (MIROC5), intermediate (CCSM4), to relatively hot and moist (CNRM-CM5).

The economic water value is derived by using previously estimated price elasticities of demand for urban water in southern California (Baerenklau et al., 2014b; Lee and Tanverakul, 2015; Renwick and Archibald, 1998; Renwick and Green, 2000). The average price elasticity is calculated and then used to calculate the change in price due to a change in quantity of water supplied as a result of climate change. This change in price is assumed to represent the change in value of water provisioning ecosystem service from the Angeles, Los Padres, Cleveland, and San Bernardino national forests.

Data

There are three types of pricing schemes observed in California. First, non-tiered or uniform pricing where each household pays a fixed price per hundred cubic feet (HCF). Second, tiered pricing or block pricing is where the price per HCF for the household depends upon the amount of water consumed. In the case of increasing block rates, the first few HCFs are priced relatively low whereas subsequent HCFs are priced higher such that the per HCF price increases in conjunction with consumption. It is common for water agencies to allow the first 8 or 10 HCF consumed by households to be priced at the lowest tier.

The third type of pricing is allocation-based water pricing which is a type of block or tiered pricing structure where the price per HCF depends upon the household characteristics, such household size, lot size, any relevant medical conditions, as well as a "judgement" call by the water agency regarding what an "efficient" level of use is for households given their characteristics (Baerenklau et al., 2014a). The efficient level is called the household's "water budget" and consumption beyond this level is deemed to be "inefficient." With allocation-based pricing, the amount that households pay per HCF can vary across time and households.

Several recent studies have examined residential demand of urban waters in southern California. From these econometric models, they have estimated the price elasticity of demand for water by urban households. Renwick and Archibald (1998) analyze the extent to which price and alternative policy instruments reduce residential demand and their distributional implications in their assessment of demand side management policies to manage water resources. They estimated demand using household survey and concomitant utility use and price data of residents in Santa Barbara and Goleta, taking advantage of the state wide drought from 1985-1992. These two communities were selected for their exclusive reliance on local surface and groundwater supplies. Using both tiered and non-tiered price data, their water demand model provided an estimate of -0.58 for the price elasticity of demand across Santa Barbara and Goleta.

Analysing a larger cross-sectional monthly time series data for eight water agencies in California, Renwick and Green (2000) estimated a lower price elasticity of demand (-0.16).

This study covers the effect of various demand side management residential initiatives implemented in California between 1989 and 1996, which also encompassed the drought between 1985 and 1992. The urban eight water agencies operate in a number of municipalities, including Los Angeles, San Diego, and San Francisco, collectively providing residential water to 24 percent of the state's population (over 7 million people). Both non-tiered and tiered prices were implemented by the water agencies during the study period and hence used in the demand model.

Baerenklau et al. (2014b) examine the effect of introducing fiscally neutral allocation-based water pricing on residential demand in the Eastern Municipal Water District. The data include over 13,000 single family households with continuous monthly water use records between January 2003 and September 2012. The authors estimate two separate demand functions, one using non-tiered rates and the second using the water budget data for allocation-based pricing. The estimate price elasticity of demand with non-tiered pricing is -0.76 and for water budgets data is -0.58.

The fourth and last source of demand elasticities is from Lee and Tanverakul (2015) who conducted a meta-analysis of about 1,000 households in East Los Angeles and South San Francisco. Using 10 years of monthly water consumption data (January 2002 – December 2011) from California Water Service – the largest regulated American water utility west of the Mississippi River and the third largest in the country – the authors assess the influence of price and price structures on residential water demand. These data were used to estimate and compare price elasticities for periods when non-tiered and tiered rates were charged. The estimated price elasticity for East Los Angeles was -0.39 and -0.44 for non-tiered rates and tiered rates, respectively.

Table ***1*** below identifies the price elasticity of demand and their average that are used in this paper.

Table 1: Water Price Elasticity of Demand in Southern California

Author	Year of Study	Price Elasticity of Demand	Pricing Structure	Notes
Renwick and Archibald	1998	-0.58	tiered and non-tiered	Covers drought from 1985-1992
Renwick and Green	2000	-0.16	tiered and non-tiered (combined)	1989 – 1996; 24% of CA population
Baerenklau et al.	2014	-0.76 and -0.58	tiered and water budgets, respectively	2003-2014; Eastern Municipal Water District
Lee and Tanverakul	2015	-0.39 and -0.44	non-tiered and water budgets	2002-2011; East LA

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