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Editorial

Special Issue on Economics of Salinity Impacts and Management

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Salinization of soil and water sources is a detrimental process accompanying the human civilization for thousands of years (it was water and salinity that have caused population and cultural centers rise and fall along the Tigris-Euphrates valley in ancient Mesopotamia (Hillel 2000)), and the challenges still exist. To date, about 11% of the irrigated lands worldwide are affected by salinity, and an even larger area is subject to water logging and other salinity related effects (FAO 2011). Coping with water stress and salinity conditions will become even more challenging given the global population-growth projections reaching nearly 11 billion at the end of the 21st century (Roser 2015); this will increase the demands for domestic and irrigation water, and, in turn, the pressures on natural freshwater resources. The water-stress trend is expected to be exaggerated by the continuous warming process associated with climate change, particularly in subtropical dry regions where mean precipitation will likely decrease (IPCC 2014). Indeed, the use of marginal and desalinated water is on the rise (Assouline *et al.* 2015).

Salinity is the subject of a vast body of literature in different disciplines; most of it refers to agricultural impacts. Agronomic studies attempt at understanding and estimating the salinity impacts on crops (Wallender and Tanji 2011). Various numerical models were proposed to describe yields' integrative responses to water quantity and salinity (e.g., Maas and Hoffman 1977; Letey *et al.* 1985; Shani *et al.* 2007). At the plant level, research in the areas of plant physiology, genetics and biochemistry provides deeper understanding of plants' complex responses to abiotic stresses, and the mechanisms available for breeding and improving plant tolerance to saline conditions (Foolad 2007; Jewell *et al.* 2010; Tuberosa 2014). On a larger scale, examination and modeling of hydrological processes help understand salt transport and accumulation in regional systems affected by anthropogenic and natural factors (Schoups *et al.* 2005; Suweis *et al.* 2010), and the associated impacts on ecosystems (e.g., Jolly *et al.* 2008; Pitman and Läuchli 2002).

This special issue belongs to the branch of literature that addresses the salinity problem from an economic perspective. Economists relay on knowledge produced by other disciplines, and integrate the information into models so as to conduct economic analyses of water management under optimal conditions, identify technologies and strategies to increase efficiency, recognize and estimate damages associated with market failures, and suggest policies to alleviate their impacts (Dinar and Zilberman 2012; Knapp 1999; Feinerman 2000). Advanced analytical methods have evolved along recent decades, and hydro-economic models now integrate multi sectoral water demands, various water-supply alternatives, environmental effects, stochastic spatio-temporal processes, and institutional and physical constraints (Booker *et al.*, 2012; Harou *et al.* 2009). Yet, incorporation of salinity and other water-quality indicators into the scope of analysis is still a challenge. This special issue is an attempt to contribute along this course, where the wide range of topics presented by the papers illustrates the variability and extent to which salinity affects human welfare.

The paper by MacEwan *et al.* demonstrates the complexity associated with deriving policy-relevant economic assessments under the limitation of data availability, in this case, for the Kern County, California. An integrative system of estimated/calibrated models is used to evaluate salinity costs, while incorporating the assumption that farmers adapt to salinity levels by employing instruments in both the field and regional scales. In relation to the adaptation assumption, two of their findings are of particular interest. First, using a multinomial model, they estimate the impact of salinity on farmers' selection of crop portfolios. Apparently, the probability of crop to be included in a portfolio correlates with the crop's salinity tolerance as found by agronomic experiments — the higher the salinity, the higher the probability of tolerant crops to be grown. This verifies that farmers indeed apply rational acreage responses to salinity. Second, the authors estimate a behavioral field-level yield-salinity production functions which, unlike the experimental ones, incorporate the impact of unobserved adaptation instruments; for instance, changing water applications. They find that the behavioral functions predict considerably lower salinity impacts relative to the experimental functions. This finding supports the aforementioned filed-level adaptation assumption. These are unique rigorous evidences for the validity of the field and regional adaptation assumption, which is so commonly used in mathematical-programming-based studies (e.g., Kan and Rapaport-Rom 2012).

Haensch *et al.* utilize a unique database from the Murray–Darling Basin of Australia to study the relationship between salinity and the patterns of trade in the markets of permanent and temporary surface water entitlements. Specifically, they test three hypotheses. The first claims that farmers encountered with higher dryland salinity would face difficulties in producing high-value crops, and would therefore tend to sell their surface water entitlements. This hypothesis implies that dryland salinity is considered chronic, and is indeed verified statistically. Second, groundwater is viewed by farmers as a substitute to surface water; hence, farmers in regions with higher groundwater salinity would purchase higher volumes of surface water. Also this hypothesis is statistically supported by the data. The third hypothesis asserts that surface water constitutes an important factor in the production of high-value crops; therefore, the higher the surface-water salinity in a region, the higher the probability of surface-water entitlements to be sold out. The authors find only weak support for this hypothesis, and suggest that a variety of strategies may be applied to cope with surface-water salinity.

Azad and Ancev consider the internalization of salinity-related environmental impacts into agricultural policy making. They apply the environmental performance index (EPI) (EPI; a measure that incorporates both the economic benefits and the environmental damages of an economic activity) to the case of cotton production in New South Wales, Australia, and rank cotton-producing regions according to their computed EPIs. It is found that, despite the considerable variation, most of the regions perform within an acceptable range. The authors suggest using the rank as an instructive tool for directing deeper investigation of the factors deriving the EPI variability, such as soil quality, topography, adoption of irrigation technologies, etc. For example, a consistent spatial distribution is found such that down-stream regions are more efficient than the upstream ones. In addition, the rank may be used by policymakers to better direct water monitoring and environmental regulations.

The paper by Baum *et al.* treats the management of water sources under freshwater-stressed conditions based on a general equilibrium approach. Using the case of Israel, they develop a CGE model wherein the rates of constant-elasticity of substitutions between agricultural water sources are estimated by the use of a partial-equilibrium positive-mathematical-programming model. This link enables to capture the economy-wide implications of changes in the availability of naturally renewed freshwater sources while accounting for the various field- and farm-level strategies available to farmers to adapt to changes in the relative prices of water sources with diversified salinities, as well as for food-security limitations associated with irrigation with treated wastewater. The take-home messages of the study are (1) that freshwater shortage can have a considerable impact on Israel's GDP, most of it is channeled through the agricultural and manufacturing sectors, and (2) that the effect can be efficiently avoided by the installation of desalinated plants. The authors also suggest a wide range of extensions to their work.

While a large portion of the research efforts on salinity are directed to its agricultural aspects, the study by Dasgupta *et al.* reminds us that many developing countries encounter severe difficulties in providing access to fresh drinking water, and therefore face the associated health effects. Their work focuses on the impact of exposure to salinity in coastal Bangladesh on infant mortality. Apparently, the most sensitive period is at the last month of pregnancy, in which exposure to salinity increases the mortality probability of infants less than two months old. The extent of the effect is at the same magnitude as that of well-known infant-mortality factors, including maternal age and indicators of household wealth and sanitary conditions. The authors conclude that infant survivability could be dramatically increased by supplying freshwater to pregnant women at this short but critical period, and suggest that farther research may encourage policies and altruistic actions to raise financial support for this purpose.

So far salinity problems have developed and remained for long periods, and it is not obvious that they will vanish, even in the far future. Mitigation and adaptation strategies (e.g., using drip irrigation, installing subsurface drainage systems and altering cropping patterns) are already well-known, but their economic viability depends on complicated physical spatio-temporal stochastic processes, as well as a wide range of interlinked factors. Population growth augments the demand for freshwater for domestic use, and at the same time increases the sewage amounts needed to be disposed of. This process incentivizes the replacement of fresh- with nonfresh irrigation water sources, and thereby speeds up salinization of soils and aquifers. On the contrary, the demand for agricultural products may be shifted upward, thereby increases the demand for natural freshwater irrigation, which in turn may be balanced by technological improvements that enlarge agricultural wateruse efficiency. The water-energy nexus may play a crucial role by affecting the expansion of desalination of sea- and treated waste water, and governments can enhance salinization through distorting intervention policies. This special issue provides only a glance into some of these issues that compose the picture of the economics of salinity impacts and management.

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