

Agent-Based Model Development and Touchet Watershed Data Usage

Using agent-based modeling (ABM) and water rights data from the Touchet River Basin in eastern Washington, these two studies explore different economic and environmental impacts related to water rights and streamflow augmentation. Together, these studies offer valuable insights for developing sustainable water resource policies that balance economic gains with environmental and social impacts.

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This research highlight is based on a published work (see last page).



Study 1: Assessing Water Markets and Upstream Trade Impacts

Under the prior appropriation system in the western U.S., water rights are described as “first in time, first in right” because the date of first water use determines the user’s priority to use the water. In this system, water is often acquired through diversions and water users can sell or lease their rights to use the water. Water sales and leases usually transfer the consumptive use amount of water to avoid third-party impacts. Despite the potential economic gains, upstream transfers that might harm intermediary water rights holders are generally disallowed.

Water markets are increasingly used to reallocate water from low to high value uses, particularly in regions where existing water resources are fully allocated. However, water markets often face restrictions, such as prohibitions on water right transfers from downstream to upstream users, due to potential negative impacts on other water rights holders. These restrictions can limit potential gains from trade. Third-party impacts may result from imperfect definition, measurement, or enforcement of water rights, affecting both supply and environmental quality.

This study examines the economic consequences of allowing or

prohibiting upstream water leasing, where the value of water rights is linked to irrigation. The study uses an agent-based model (ABM) to simulate interactions between water rights holders with and without upstream trade restrictions, allowing the observation of economic and water distribution consequences with high accuracy. The model is modified to account for stream flows, trade externalities, and imperfect information. It quantifies gains from trade, externalities, and net social benefits, comparing scenarios involving actual consumptive uses, mismeasured consumptive uses, and diverted water (Figure 1).

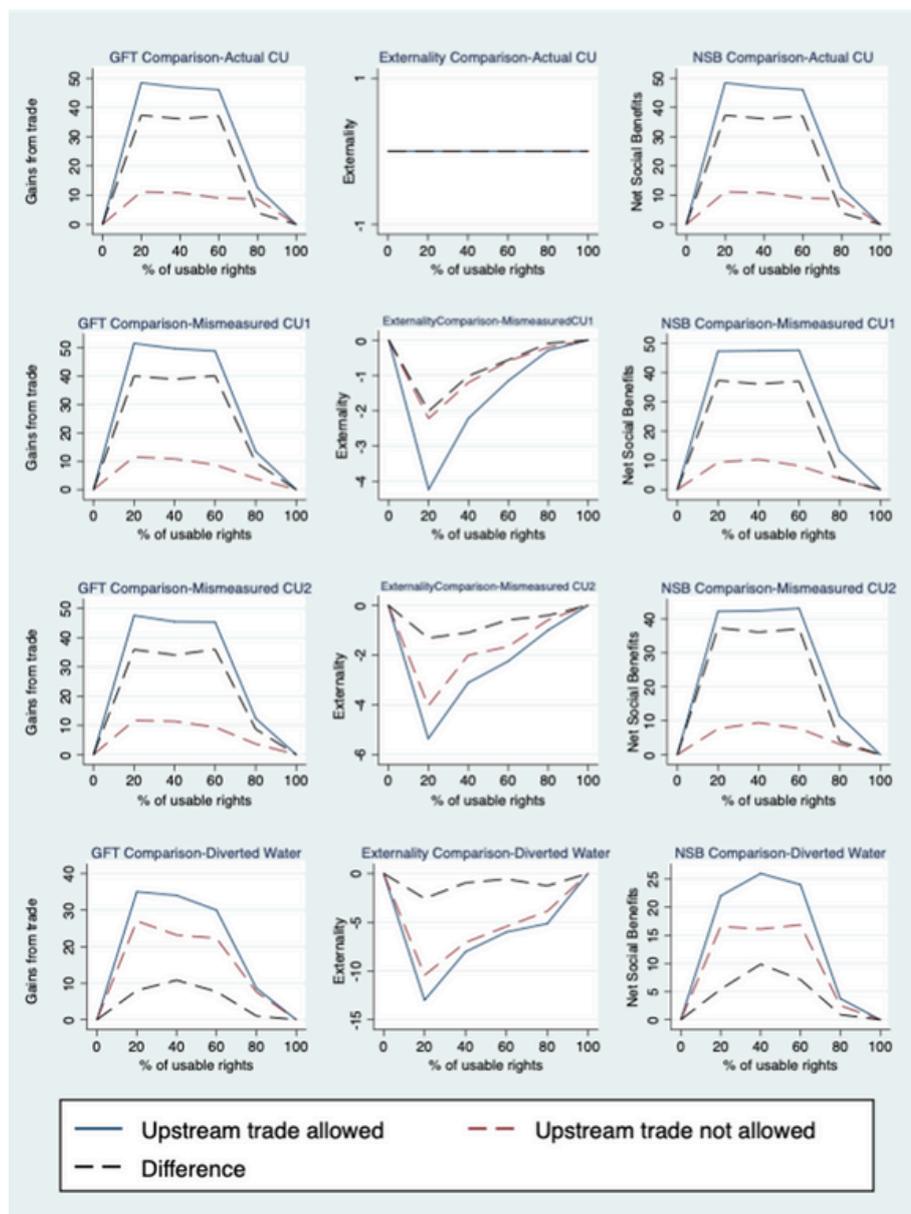


Figure 1. Comparison of gains from trade in three scenarios: Gains from Trade (GFT; Column 1), Externality (Column 2) and Net Social Benefit (NSB; Column 3) when upstream trade is allowed vs. not allowed with four different trade amounts: Row 1: Actual Consumptive Uses - The gain from trade is always higher when upstream trade is allowed. Rows 2 and 3: Miscalculated Consumptive Uses - There is no negative or positive externality associated with trading consumptive use amount of water but trading other amounts result in negative externality. and Row 4: Diverted Water - The Net Social Benefit is higher for when upstream trade is allowed. Externalities associated with one-to-one trading of diversion rights leads to the largest negative externalities.

In the Touchet River Basin, the ABM simulations confirm that gains from trade are higher when upstream trade is allowed across all scenarios. Optimal trade gains are achieved when approximately 20% of water rights are usable, depending on streamflow. The findings suggest that trading

based on accurate consumptive use amounts prevents negative impacts on diversion rights from trade, even when upstream trade is allowed. However, mismeasurements of consumptive uses can lead to negative externalities, and accounting for environmental and ecological

values of streamflow would likely increase these externalities, potentially leading to lower net social benefits. Therefore, upstream trade may be disallowed under circumstances where negative externalities outweigh the gains from trade. While upstream transfers can cause externalities,

allowing them generally leads to higher gains. Accurate consumptive use-based trading prevents negative impacts, guiding policy decisions on upstream trade conditions and water transfer amounts.

Figure 2 shows that the percentage of agents trading when actual consumptive use amounts are traded is maximum at streamflow that accommodates 20% of the rights to be used, with 44.55 % of agents trading when upstream trade is allowed as against 22.61% when upstream trade is not allowed. This is consistent with the gains from trade in Figure 1. The percentage of agents trading when consumptive uses are mismeasured (instance 1) is a maximum of 23.13% when upstream trade is not allowed and 44.03% when upstream trade is allowed, both at 20% rights usable. When consumptives uses are mismeasured (instance 2), a maximum of 24.63% of agents trade when upstream trade is not allowed, and 46.28% trade when upstream trade is allowed at 20% of usable rights. When diverted water is traded, gains are maximized (Figure 1) at 20% of uncurtailed water rights, consistent with the maximum agents trading at 45.52% when upstream trade is allowed and 27.61% when upstream trade is not allowed (Figure 2).

Study 2: Economic Consequences of Streamflow Augmentation with Downstream Appropriators

The second study simulates the economic impacts of water rights leasing for streamflow

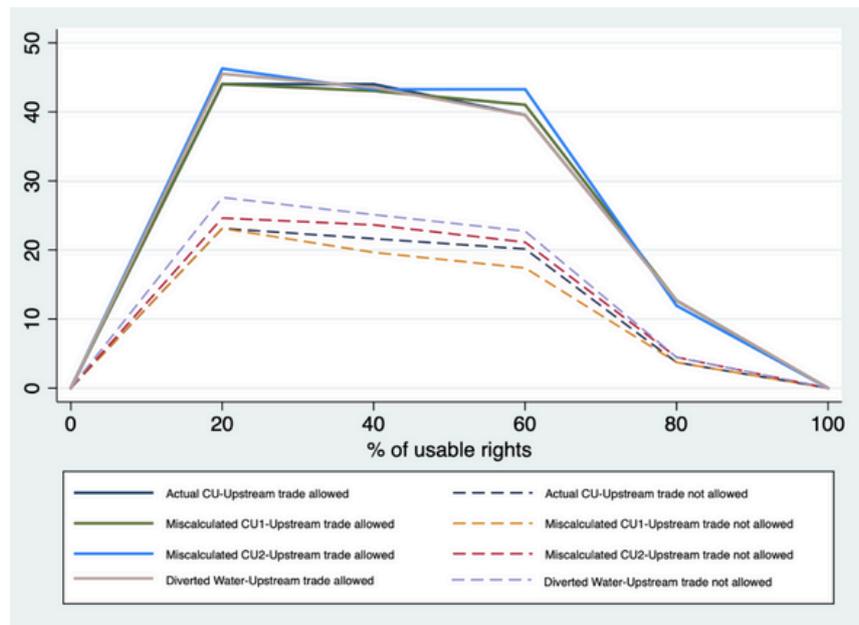


Figure 2. Percentage of agents trading. The number of agents trading is lower by about half under all scenarios when upstream trades are disallowed.

augmentation under varying drought conditions. Streamflow, the volume of water flowing past a specific location in a stream or river, is crucial for both economic and environmental outcomes. Improved streamflow benefits ecosystems through enhanced services such as recreation, nutrient removal, and aquatic habitats. In the Western U.S., balancing off-stream water uses (e.g., irrigation) with instream requirements (e.g., water quality, power generation) has been a longstanding challenge. Water trusts, private non-profit organizations, aim to enhance stream flows by acquiring water rights, primarily in the Western U.S.

In this study, we assume the Water Trust aims to acquire 10% of available water rights for streamflow augmentation, prioritizing senior rights with the highest river miles per dollar

opportunity cost. Opportunity cost explains the relationship between scarcity and choice. Under the circumstances assumed in this study, the opportunity cost reflects the foregone irrigation value associated with the water rights that are purchased by the Trust.

The study examines two scenarios: one where downstream users are prohibited from diverting augmented flows and another where such diversions are allowed. The ABM simulates interactions among 134 water rights holders and the Trust, balancing purchases and opportunity costs to optimize streamflow augmentation. The model incorporates the Smart Market trading mechanism to observe the economic effects of water trusts participating in the market alongside other buyers and sellers.

The Trust seeks to minimize costs associated with streamflow

augmentation, balancing the purchase of water rights with their opportunity costs. When downstream appropriators are prohibited from diverting augmented flows, the Trust incurs lower costs (Figure 3).

Conversely, when downstream diversion is allowed, the Trust must purchase more water rights, increasing the costs. The augmented flow maintains higher stream levels throughout the river when diversion is prohibited (Figure 3). When diversion is allowed, flow levels decrease significantly downstream, reducing the ecological benefits. The costs and effectiveness of streamflow augmentation vary with drought severity. Under severe drought conditions, the Trust faces higher costs due to the scarcity of available water rights and increased competition from other buyers.

The ABM highlights the economic and environmental trade-offs in streamflow augmentation. Effective regulatory frameworks are crucial to optimize streamflow benefits, informing policies for sustainable water resource management. The economic analysis of water rights leasing for streamflow augmentation provides insights into the cost differences under various legal and

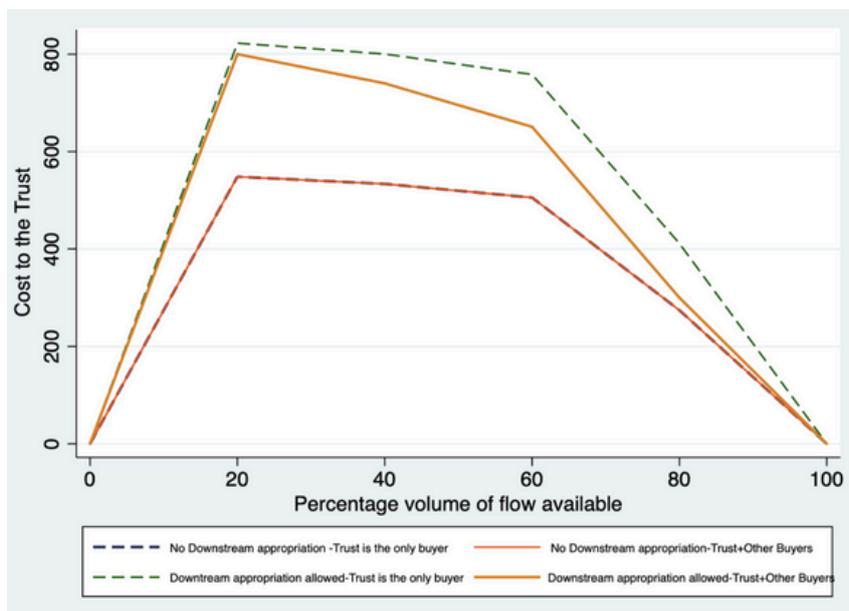


Figure 3. Cost to the water trust

environmental scenarios. The study underscores the importance of regulatory frameworks in streamflow management, demonstrating how legal restrictions on downstream appropriators can significantly impact the costs and effectiveness of augmentation efforts.

Conclusions

Both studies provide significant economic and regulatory insights. The first study quantifies gains from trade and externalities under various scenarios, emphasizing the importance of accurate measurement of consumptive use. The second study evaluates the

cost implications and effectiveness of streamflow augmentation under different regulatory scenarios, highlighting the role of legal restrictions. Together, these studies offer valuable insights for developing sustainable water resource policies that balance economic gains with environmental and social impacts. The findings support the development of comprehensive regulatory frameworks to optimize streamflow benefits and inform policy decisions aimed at sustainable water resource management in drought-prone region.

Reetwika Basu, Ph.D. is an economist and research scientist for NASA Earth and Applied Sciences program in the SERVIR Science Coordination Office. This work is part of Dr. Basu’s Ph.D. dissertation (2023).

Full paper available at:

Basu, R., 2023. Three Essays on Agent-Based Model for Water Allocation Under Appropriate Rights. Washington State University.

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