POTENTIAL FOR A HYBRID POPLAR INDUSTRY USING RECYCLED WATER:

AN ENVIRONMENTAL APPLICATION OF POPLAR IN IDAHO

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POTENTIAL FOR A HYBRID POPLAR INDUSTRY USING RECYCLED WATER: AN ENVIRONMENTAL APPLICATION OF POPLAR IN IDAHO

By,

Nora Haider, Extension Coordinator Senior, WSU Extension, Washington State University; **Nathan Parker**, Senior Sustainability Scientist, School of Sustainability, Arizona State University; and **Patricia A. Townsend**, Regional Extension Specialist, Agriculture and Natural Resources, Washington State University

Introduction

In northern Idaho, water quality regulations prevent the discharge of treated wastewater into the Spokane River during summer months when in-stream flow is low. This creates a water surplus challenge for municipal wastewater treatment facilities in the Spokane Valley, such as the Hayden Area Regional Sewer Board (HARSB). In response to this challenge, HARSB established the Re-Use Farm that consists of 246 acres of annual livestock forage crops, such as alfalfa and oats, and 39 acres of poplar trees. Treated wastewater is recycled on the farm and is used to irrigate the crops and poplar trees.

HARSB likes poplar trees as a crop because the trees consume high quantities of recycled water and can remove nutrients and contaminates that remain in the water after it goes through the facility's treatment process (Table 1). While the poplar trees could be a solution to the region's wastewater discharge problems, there currently are no local markets for poplar biomass, which limits the potential of poplar as a wastewater discharge solution. HARSB harvested 15 acres of poplar grown for saw timber over the summer of 2017 to make way for additional forage crops but were only able to give the poplar away for free as firewood. HARSB is now leasing the former poplar field to farmers to generate additional revenue for the utility. The farmers use the land to produce livestock feed, irrigating the crop with treated wastewater.

Poplars grown with recycled wastewater provide a solution to a wastewater discharge problem (Jordahl et al. 2003). When grown as an energy crop, poplar also has great potential as a feedstock for a biorefinery. This potential synergy has captured the attention of researchers working on the Advanced Hardwood Biofuels Northwest (AHB) project.

Table 1. Water application rates at the HARSB facility over the summer of 2015.

	Irrigation Rates (inches/acre)		
Month	**Alfalfa**	**Poplar—tall stands planted 1993**	**Poplar—coppiced planted 2011**
June	4.79	19.31	18.78
July	4.94	21.05	20.29
August	4.07	11.96	11.17
Total	13.8	52.32	50.24

Water usage rates of alfalfa and poplar trees grown at the HARSB facility in Hayden, Idaho.

AHB is a collaboration of university and industry partners focused on laying the foundation for renewable biofuel and bio-based chemical industries in the Pacific Northwest. As a partner to these efforts, HARSB has assisted AHB in the development of a hybrid poplar research trial to demonstrate the potential of poplar trees as a bioenergy crop.

AHB introduced a new cropping system for poplars on 65 acres adjacent to the HARSB Re-Use Farm. The poplar trees were managed as a "short-rotation coppice," which means that the trees are grown on three-year cutting cycles and then coppiced. Coppicing involves cutting the trees at the base, then allowing them to resprout from their cut stumps. Due to permitting issues, these poplars were not irrigated with wastewater. However, HARSB's potential use of poplar and wastewater resources prompted an economic analysis to determine if the Hayden area could support a 31.25 million-gallon-per-year acetic acid biorefinery.

Acetic acid is an industrial chemical that is used to make plastic, wood glue, and synthetic fibers and fabrics. A biorefinery would use the cellulosic sugars present in the poplar wood and ferment the sugars to acetic acid or other high-value chemicals. The biorefinery would require a large, reliable supply of feedstock that could be converted to make these bio-products. Dedicated short-rotation poplar plantations, potentially irrigated with recycled wastewater, are proposed as a way to meet future biorefinery feedstock demands.

This example of an environmental application of poplar provides proof of concept for the development of a poplar-based feedstock supply chain for a new biorefinery in northern Idaho. This analysis demonstrates the feasibility of a biorefinery in the Hayden area and the potential cost savings to the biorefinery if poplar feedstock was grown with recycled wastewater.

Recycled Water and HARSB

Recycled water is treated wastewater that is reused for beneficial purposes, such as agricultural and landscape irrigation or industrial processes. Wastewater treatment facilities can tailor effluent processing to meet the water quality standards required for use in different applications. There are four recycled water classifications: A, B, C, and D, with the most intensive treatment producing Class A water.

The poplars on the HARSB Re-Use Farm were planted in 1993 as a solution to discharge restrictions that were put in place to protect the water quality of the Spokane River. HARSB uses recycled wastewater to irrigate forage crops through two center pivot systems (Figure 1). The poplars were irrigated with recycled water through drip irrigation lines. With proper signage and fencing to keep the public out, the HARSB facility used Class C recycled water for crop irrigation. Class C recycled water typically undergoes secondary treatment with pathogen removal. As of 2016, 48% of Idaho's municipal reuse permits were issued for Class C approved uses (Plaisted 2016).

Figure 1. HARSB irrigates forage crops with recycled wastewater coming from a center pivot irrigation system at the HARSB facility near Hayden, Idaho. The facility's former poplar trees can be seen in the background. Photo credit: Ken Windram.

Regional Wastewater Treatment Plants

There are 24 wastewater treatment plants within a 75-mile radius of the HARSB facility in Hayden, ID that have water disposal restrictions during times of low-stream flow (Figure 2). These wastewater treatment plants have a combined average discharge flow rate of 63 million gallons per day. From June through August, these facilities face water discharge restrictions and need a way to responsibly dispose of approximately 17,500 acre-feet of water during the summer months.

The availability of recycled water also needs to be linked to available agricultural lands in proximity to the wastewater treatment facilities. Analysis of satellite imagery finds that all wastewater treatment plants in the region are within a few miles of large quantities of agricultural fields or grasslands. In addition, there are more than one-thousand acres of agricultural land that are directly adjacent to the treatment plants.

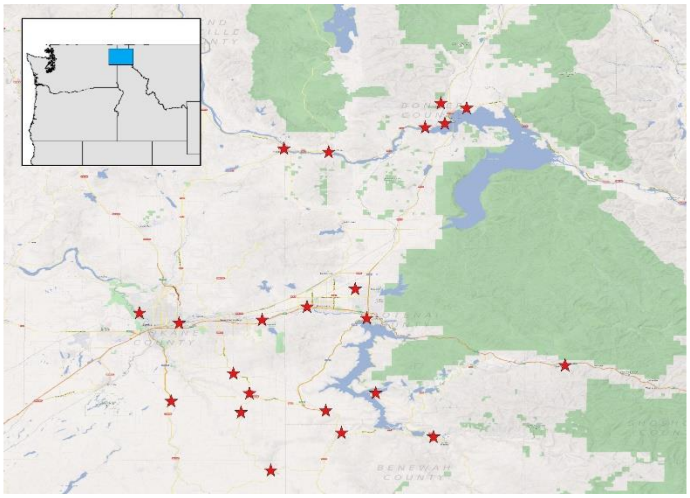

Figure 2. Location of wastewater treatment plants in the Hayden area. There are 24 municipal waste water treatment facilities within 75 miles of the HARSB facility in Hayden, Idaho. Image: Nathan Parker.

Poplar Production Potential

Poplar water consumption can vary greatly depending on the site's soil type, the time of year, and the management objectives of a particular grower. At the HARSB Re-Use Farm, the primary goal is to dispose of water while protecting local water resources. The hybrid poplar trees do an excellent job of this by taking up large amounts of water. During the summer months of 2015, the 20+ year old poplars consumed 50 inches of recycled water per acre. At this rate, the facility was able to dispose of the recycled water on a minimal amount of land, while protecting the water resources of the Spokane River.

Coppiced poplars have an increasing ability to take up water as they grow through the 3-year coppice cycle. At AHB's former demonstration site in Hayden, irrigation rates increased from 22.5 inches per acre in the first year of growth to 74.4 inches per acre in the third year. To maintain a consistent flow of poplar feedstock to the biorefinery and a consistent service of water consumption, the poplar plantations in the region will need to be planted in a staggered fashion so that there are trees in all three stages of the growth cycle at any given time. This results in an average water consumption of 49.4 inches per acre per year.

- Approximately 4,250 acres of hybrid poplar trees would be needed to consume the recycled water from all 24 wastewater treatment facilities in the region.
- There are 475 acres of agricultural land directly adjacent to the wastewater treatment facilities. (This is lower than the total adjacent land, because there is a mismatch between the size of the treatment plants, and, therefore, availability of recycled water and available adjacent land.)

Annualized yields of hybrid poplar trees in the Hayden area are estimated to average around 6 dry tons per acre, per year. Applying the yield to the area, we find that 38,500 dry tons per year of poplar biomass could be produced with full use of the available recycled water resources. If use is limited to fields immediately adjacent to the facilities, then the potential drops to 3,800 dry tons per year.

Meeting the Demand

Biorefinery Poplar Demand

Given the amount of suitable land in this region, the models show that the Hayden area could not produce enough feedstock for a large-scale, 100-million-gallons-per-year biojet fuel refinery, but it may be able to support a renewable chemical plant. Acetic acid can be produced near market prices at 1/5th the scale of a biofuel biorefinery. Producing 31.25 million gallons of acetic acid a year, an acetic acid biorefinery would require a supply of 250,000 dry tons of biomass feedstock per year. Analysis of the feedstock supply chain shows that wastewater treatment plants around Hayden could contribute 15%, or 38,500 tons, of this total (Table 2). Wheat straw residues from local agriculture and commercial poplar plantations could also be used to meet the facility's feedstock demands.

Table 2. Example breakdown of feedstock sources.

Feedstock Type	Bone-dry tons (BDT) of Biomass/Year	Poplar Acres
Poplar from wastewater treatment facilities	38,500	4,250
Poplar from other plantations	186,500	31,000
Wheat straw	25,000	
Total	250,000	35,250

An acetic acid biorefinery would require 250,000 tons of biomass per year to operate. This total could come from commercial poplar plantations, but the facility could also utilize poplar grown with recycled water and wheat straw.

Supplemental Wheat Straw Supply

Wheat straw could be a supplemental feedstock to poplar in an acetic acid biorefinery. Wheat is an annual agricultural crop grown for the grain portion of the plant. After the grain is harvested, the wheat straw remains in the field and is often burned in preparation for the planting of the next crop. Currently, wheat straw is sold for use as a substrate for mushroom growing, animal bedding, and low nutrient livestock fodder. Farmers also find value in wheat straw when it is left whole in the field to retain nutrients and organic matter.

For biorefineries located in the region, wheat straw could be a promising supplemental feedstock that could be utilized from July through September, after the wheat is harvested. The U.S. Department of Energy's Billion Ton Update (2016) estimates that there are 30,000 dry tons of wheat straw available in nearby counties in Idaho. Expanding the delivery distance into Washington, we find another 500,000 dry tons of wheat straw. We estimate that 25,000 dry tons of sustainably managed wheat straw could be brought to a biorefinery in Hayden for $80 per ton or less.

Commercial Poplar Plantations

In addition to the estimated 38,500 dry tons per year of biomass that could be produced from poplar grown with recycled wastewater and wheat straw in the area around Hayden, an additional 31,000 acres of dedicated poplar plantations would be needed to meet a biorefinery's feedstock demand. The actual required acreage depends on the ratio of irrigated farms of high productivity to non-irrigated farms of lower productivity.

A research team at the University of California-Davis created a model simulating farming choices in the region and the economics related to those choices (Bandaru et al. 2015). This model was used to create estimates of the amount and types of land that a given landowner might be motivated to convert to poplar bioenergy crops in relation to alternatives. Using the model, the team found that the adoption of poplar as a crop would most likely occur on lands that are currently a mix of non-irrigated forage crops (hay and silage), pasturelands, and a small amount of irrigated fields growing beans and barley. Simulations were also run without the use of recycled water and the adoption of poplar by wastewater treatment facilities. The results showed similar types of land use change but on larger acreages as the biorefinery relied more heavily on low-productivity, non-irrigated poplar.

The economic analysts found that the required price at the biorefinery gate is reduced by up to 15%, from $130/dry ton to $111.50/dry ton, when poplar grown with recycled wastewater and wheat straw are available (Figure 3). This price effect is the result of avoided production from the most expensive, irrigated poplar sources that would have been needed to fully supply the biorefinery. This level of reduction would require the full participation of all wastewater treatment plants and the majority of wheat growers in the nearby counties.

Figure 3 shows the biomass supply curve for an acetic acid biorefinery. The solid black line on this graph represents a marginal cost curve for commercially-grown poplar in the Hayden area. This line only represents feedstocks grown on traditional commercial poplar plantations, not poplar grown with wastewater. The graph shows that if a biorefinery was willing to pay $60/BDT for poplar, local growers would be willing to supply only a negligible amount of poplar. At the top of the supply curve (black dashed line), where a biorefinery would

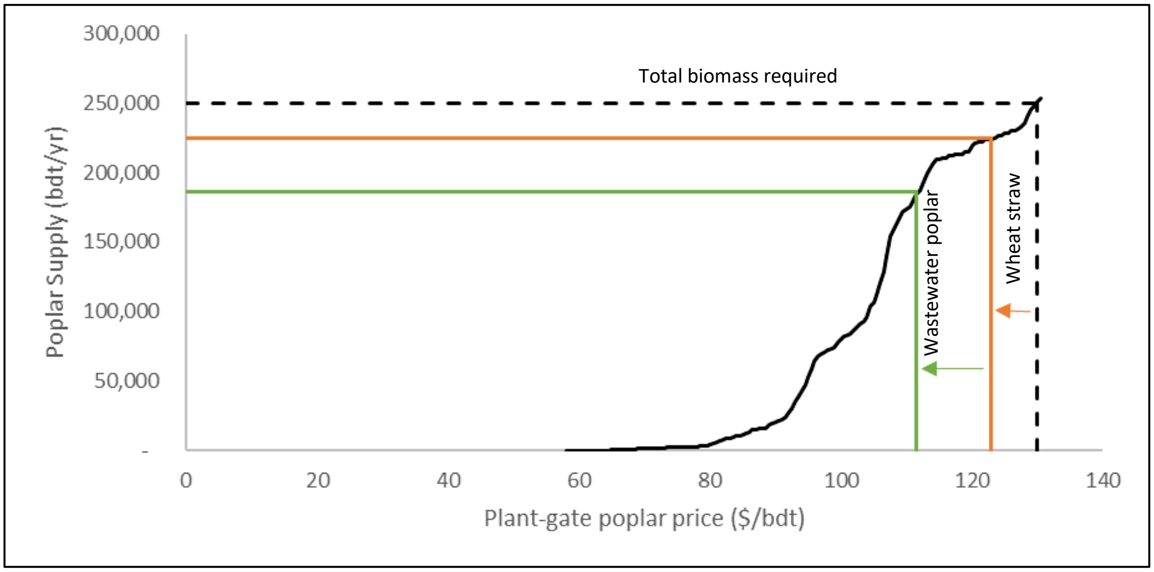

Figure 3. The biomass supply curve for a biorefinery in Hayden that only utilizes feedstock grown on traditional, commercial poplar plantations. The orange and green sections represent the cost saving that can be achieved if wheat straw and poplar grown with wastewater were introduced into the supply chain. Image: Nathan Parker.

be paying $130/BDT, poplar growers would be willing to meet all of the biorefinery's feedstock demand of 250,000 BDT of poplar per year. The graph shows that if wheat straw (orange lines) and poplar grown with recycled water (green lines) are introduced into the biorefinery's feedstock supply, the demand for commercially produced poplar would be reduced. Under this scenario, with both wheat straw and wastewater poplar available for a feedstock, the hypothetical biorefinery would only require about 186,500 BDT of commercially grown poplar. The model shows that if wheat straw was introduced into the supply chain, the price paid for traditionally grown poplar would be reduced to about $123/BDT. If poplar grown with wastewater was introduced into the supply chain, the biorefinery could meet its demand for poplar at around $111.50/BDT. This decrease is the result of avoided poplar production at the top of the supply curve.

Limitations of the Study

This should be considered a hypothetical description of a biorefinery feedstock supply chain. The intent of this analysis is to demonstrate how a biorefinery could reduce their feedstock cost by partnering with local wastewater treatment plants. The ideas presented here are based on economic models, rather than field experiments. Also, feedstock prices are from the perspective of the biorefinery, so many of the nuances of a successful poplar production system have been, by necessity, overlooked. Many potential costs and risks, such as pest and disease treatments, irrigation failures, and other potential problems, were not included in this analysis. The study also assumes robust participation by the region's farmers, which may be an optimistic assumption.

Next Steps

Opportunities for poplar biomass are currently limited across the Pacific Northwest due to the low cost of petroleum fuels. From the economic perspective, poplar-based biofuels and bio-products will continue to be limited until they can economically compete with petroleum-based products. The cost savings achieved by a wastewater treatment plant that adopted land applications of treated effluent, rather than more extensive tertiary treatment, is another avenue of research that could be explored in a benefit-cost analysis. In the meantime, AHB will continue investigating feedstock production and conversion to biofuels and bio-based chemicals. This research is complemented by additional feasibility studies to identify the most efficient location for a biorefinery in the Pacific Northwest. However, this environmental application demonstrates that marrying poplar production with wastewater treatment and residues from agricultural fields has the potential to provide a solution to a treatment problem, while also providing feedstock for the bioeconomy.

For More Information

Advanced Hardwood Biofuels Northwest

Hayden Area Regional Sewer Board

Poplar and Willow Forum 2016

Economic Evaluation of Potential Biorefineries with High-Resolution Decision Support Tools

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