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Stakeholder Assessment of the Feasibility of Poplar as a Biomass Feedstock and Ecosystem Services Provider in Southwestern Washington, USA

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Abstract: Advanced Hardwood Biofuels Northwest (AHB), a USDA NIFA-funded consortium of university and industry partners, identified southwestern Washington as a potential location for a regional bioproducts industry using poplar trees (*Populus* spp.) as the feedstock. In this qualitative case study, we present the results of an exploratory feasibility investigation based on conversations with agricultural and natural resources stakeholders. This research complements a techno-economic modelling of a hypothetical biorefinery near Centralia, WA, USA. Interviews and group discussions explored the feasibility of a poplar-based bioproducts industry in southwestern WA, especially as it relates to converting land to poplar farms and the potential for poplar to provide ecosystem services. Stakeholders revealed challenges to local agriculture, past failures to profit from poplar (for pulp/sawlogs), land-use planning efforts for flood mitigation and salmon conservation, questions about biorefinery operations, and a need for a new economic opportunity that “pencils out”. Overall, if the business model is convincing, participants see chances for win-win situations where landowners could profit growing poplar on otherwise low-value acreage and achieve ecosystem services for wastewater or floodplain management.

Keywords: woody bioenergy crop; social acceptance; short rotation coppice; bioeconomy; biorefinery; land-use; agriculture; crop adoption; wastewater; floodplain

1. Introduction

Hybrid poplar trees (*Populus* spp.) have a long history of cultivation in the Pacific Northwest (PNW) for a variety of uses [1,2]. In the 1980s and 1990s, poplar was established for pulp and paper. In the 2000s, the poplar tree industry transitioned to saw log and peeler log production due to poor market prices for poplar chips. Looking toward future markets, poplar could be a feedstock for bioproducts, including fuels and chemicals [3]. “Poplar for biomass” trees would be grown as a perennial agricultural crop, harvested on two- to three-year rotations (i.e., coppice) [4].

Another use of poplar trees is to provide ecosystem services. Poplar is capable of phytoremediation (using plants and their associated microbes to remove contaminants), making it effective for environmental clean-up (e.g., land reclamation) [5–7]. Many municipalities in the PNW use poplar plantations to aid with wastewater and biosolids management [8–10]. Poplar can also be planted as buffers along degraded river systems to treat nonpoint-source pollution, provide shade, prevent erosion, sequester carbon, lower peak flood flows, and provide recreation and aesthetic benefits [9,11–13].

Since 2011, Advanced Hardwood Biofuels Northwest (AHB, a consortium of university and industry partners led by the University of Washington) has been laying the foundation for a poplar-based bioeconomy in the PNW (hardwoodbiofuels.org). Originally focused on poplar for biofuels, the project expanded into exploring poplar's joint potential to provide biomass (for various bioproducts) and ecosystem services. This could lead to win-win opportunities by improving the local environment, decreasing the cost of biomass production, and benefiting rural economies.

Based on models of land-use, crop prices, poplar growth, and other factors, AHB identified southwestern Washington as a potential location for a regional poplar bioproducts industry [14]. Agricultural and pasture land in southwestern WA could produce reasonably-priced hybrid poplar biomass. Techno-economic modelling indicates many possible sites in this region for a moderately-sized (250,000 dry tons of biomass/year), cost-effective biorefinery. If the biorefinery could be co-located with the TransAlta power plant in Centralia, WA, USA there is an opportunity for major capital savings. The biorefinery would save costs by utilizing the power plant's excess boiler capacity or low-pressure steam that has modest value for power production.

If poplar farms can simultaneously provide ecosystem services for southwestern WA, this would increase the area's potential for a poplar-based bioeconomy (Figure 1). In particular, wastewater and floodplain management applications show potential. The Chehalis Regional Water Reclamation Facility already utilizes poplar, irrigating a 176-acre poplar tree plantation with reclaimed water during times when the Chehalis River has low flow, typically April through November [15]. Flooding is a major concern in the region, as the Chehalis River Basin has experienced multiple devastating floods in the past 30 years. Researchers are investigating whether land suitable for poplar plantations exists near other wastewater treatment facilities and are exploring how poplar can be incorporated into floodplain modelling.

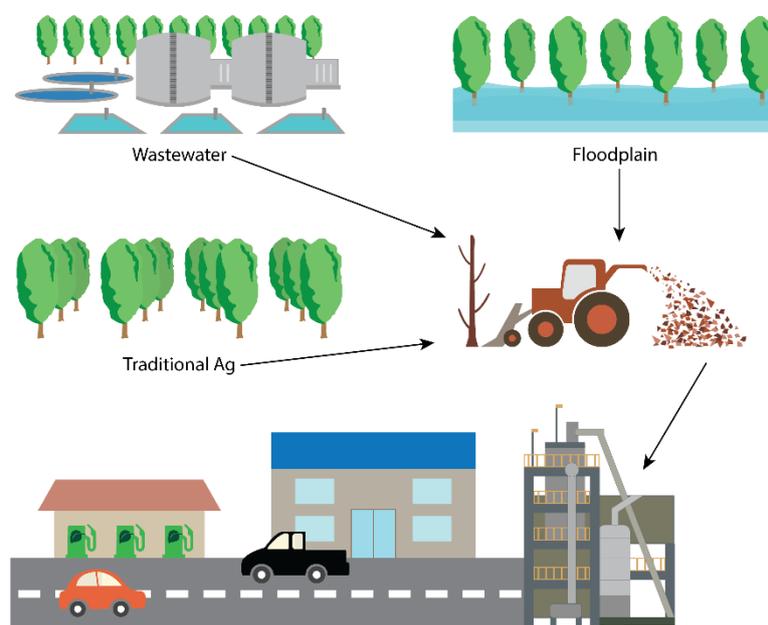


Figure 1. Potential sources of poplar biomass for a biorefinery, including traditional agriculture and ecosystem services plantings.

While techno-economic feasibility is critical, so is practicality and social acceptability. Our study takes a first step toward evaluating whether a poplar bioeconomy is practical and socially acceptable from the perspectives of people from the local agricultural/natural resource community in southwestern WA. We conducted a qualitative case study for a hypothetical poplar-based bioindustry centered around a biorefinery in Centralia, WA, USA. We used interviews and group discussions with agricultural and natural resources stakeholders to:

1. capture information about the specific context of the study region,
2. identify opportunities, challenges, and questions related to growing poplar for a bioproducts industry, and
3. explore the feasibility of incorporating ecosystem services.

Within the PNW, there are few publications on stakeholder views about poplar biomass [16,17]. A survey of WA landowners found that 36% of landowners are at least somewhat willing to grow poplar [17]. Willingness to grow poplar was connected to interest in new crops and general interest in bioenergy crops, which in turn was correlated to profit, tradition, and soil preservation.

Based on studies of other bioenergy crops in other regions, potential growers may be concerned about the status of the biomass market, failures of past introduction of new crops, unfamiliarity with the cropping method, and uncertainty about financial security [18,19]. For short rotation woody crops, farmers may not feel that the crops fit their identity, lifestyle, farming culture, and prioritization of food production [20]. Other major barriers to a new bioeconomy are likely to include concerns related to the biorefinery (e.g., increased traffic, water usage) [21] and economic challenges for commercial-scale biofuel production [22].

A new poplar bioeconomy needs a foundation of dedicated growers, receptive communities, interested biorefinery investors, and enthusiastic policy makers and community leaders. To build this foundation, we need to understand the values, needs, and concerns of those stakeholders. This stakeholder assessment is the first published qualitative study of perspectives on poplar as a biomass feedstock and ecosystem services provider, to the best of our knowledge. Specifically, we explore whether a poplar bioeconomy would fit the needs, values, and context of southwestern WA based on the knowledge of local agricultural and natural resources stakeholders.

2. Materials and Methods

2.1. Study Region

The study region (Figure 2) roughly matches a techno-economic assessment model of a hypothetical biorefinery adjacent to an existing power plant (TransAlta, Centralia Generation) in Centralia, WA, USA [23]. The biorefinery would be supplied by poplar trees produced within 100 km (62 mi) of the site. Although poplar tree farms existed in greater abundance in the past, poplar is still currently grown in the study region. Two example sites are the City of Chehalis plantation for the application of reuse water and a 4800-acre commercial plantation in Clatskanie, OR, USA, owned by GreenWood Resources Inc. (Portland, OR, USA).

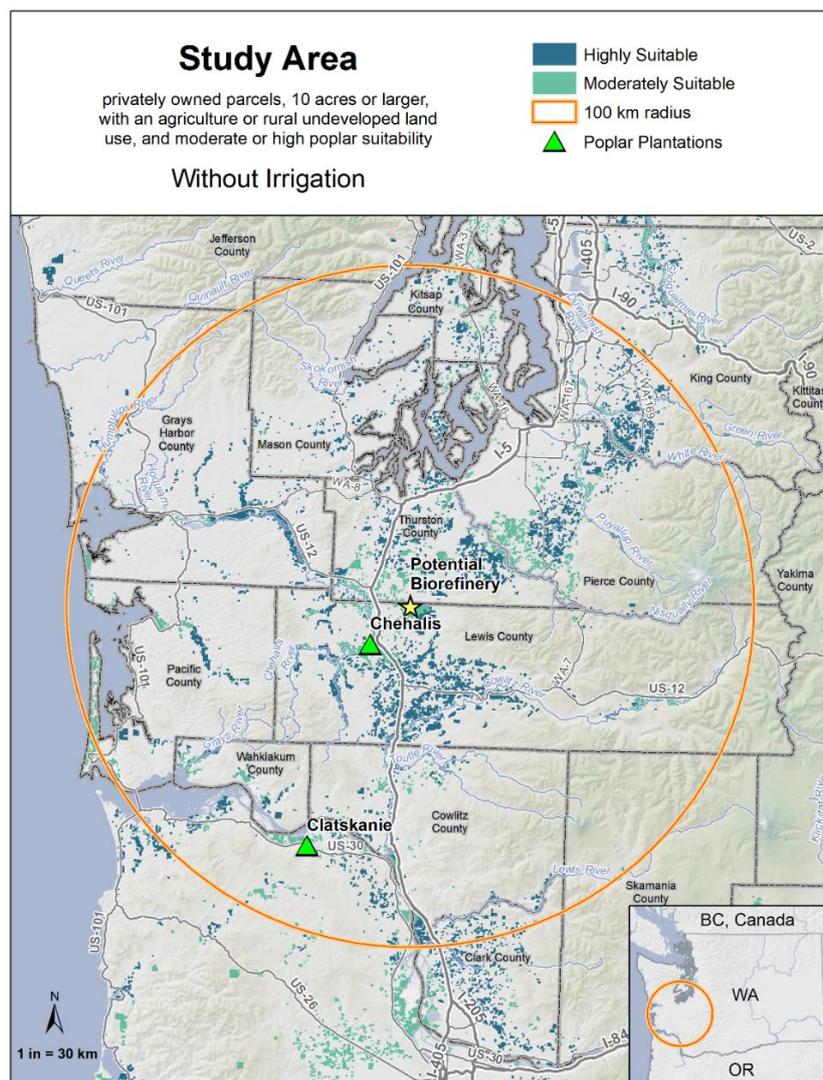


Figure 2. Parcels suitable for poplar growth without the use of irrigation within 100 km of a potential biorefinery in Centralia, WA, USA [24]. (Note: The techno-economic assessment used 100 km road distance between parcels and the potential refinery. We used a 100 km radius straight-line distance, making our study region larger.) Suitability is based on soil type, topography, and other geophysical site characteristics. Most parcels labelled as moderately suitable become highly suitable with irrigation. Map produced by Andrew Cooke, Natural Resources Spatial Informatics Group, Precision Forestry Cooperative, University of Washington.

2.2. Interviews and Group Discussions

We conducted 16 semi-structured interviews and two group discussions (one focus group and one short group discussion) with agricultural and natural resources stakeholders. By using qualitative research methods (e.g., interviews), we were able to explore a breadth of values and gain a deeper understanding of participants' rationales [25]. This is in contrast to quantitative techniques (e.g., surveys), for which participant responses are limited to preselected options or short answers.

Interviews took place in-person or over-the-phone between January–May 2018, and typically lasted 30–60 min. The focus group was conducted in January 2018 during a Chehalis Basin Partnership meeting and lasted 90 min (Appendix A). The short group discussion took place during 20 min of the February 2018 Lewis County Farm Bureau meeting. In total, we heard from approximately 33 participants.

Interviewees were recruited through purposeful sampling and snowball sampling [25]. Stakeholders came from: environmental consulting agencies, a county conservation district, WSU Extension, farming operations, non-profit conservation/landowner organizations, WA Department of Ecology, economic/land development interests, and wastewater treatment plants (Table 1). Nearly all stakeholders resided or worked on projects in Lewis or Thurston County. To learn about some of the other counties in the study region, we spoke with one stakeholder about Pierce County, another about Cowlitz County, and some stakeholders in the Chehalis Basin Partnership spoke about Grays Harbor County. Although members of tribal nations are important stakeholders in the study region, we did not seek out direct participation from tribal nations due to time and budget constraints.

Table 1. Number of individuals interviewed in each stakeholder group *. These numbers do not include participants in the focus group or short group discussion unless they were also interviewed.

Stakeholder Group	Number of Interviewed Participants
Environmental Consulting Agencies	2
County Conservation District	2
WSU Extension	3
Farming Operations	3
Non-Profit Conservation/Landowner Organizations	2
WA Department of Ecology	1
Economic/Land Development Interests	2
Wastewater Treatment Plants	3

* There are more individuals [18] than the number of interviews [16] because two interviews had two participants.

Interviewees were provided background information factsheets (Appendix B), and group discussion participants were given a presentation. An interview guide (Appendix C) structured the conversation with flexibility to explore ideas and expertise of the participants. We asked our participants to consider three different applications of poplar farms—traditional agriculture, wastewater management, and floodplain management. To explore the potential for an industry, we asked participants to assume that a market was available for the poplar. We focused on the acceptability and likelihood of poplar farming, and we also noted comments related to the potential biorefinery. We included questions about both challenges and opportunities to address potential bias toward optimistic or pessimistic views that may have otherwise arisen given our personal experience as AHB researchers.

The conversations were recorded and then fully transcribed (see Appendix A for exception). The transcripts were coded using descriptive and initial (i.e., open) coding methods to sort the data based on recurrent topics [26]. The codes were then further categorized based on our research objectives. Coding was conducted by a single researcher, using a word processor. The transcript data was reviewed and interpreted by a second researcher to ensure validity. Discussions with co-authors and a research assistant (Catherine Gowan, WSU Extension) refined the interpretation.

Participants voluntarily agreed to take part in the study and consented to an audio recording. The recordings were deleted upon completion of this manuscript. The WSU Office of Research Assurances found this project to be exempt from the need for IRB review.

2.3. Limitations

The information garnered is not generalizable to the entire population of the study region, or to all agricultural or natural resources stakeholders in the region. Given time and budget constraints, we were generally unable to interview more than one or two people from the same line of work. (This is especially relevant for the wastewater treatment case, as much of the pertinent information came from a single, highly-knowledgeable interviewee.) Instead, we looked for a wide assortment of natural resource and agricultural professionals to get a breadth of contextual information. This approach

is justifiable for an exploratory study of variability in perspectives and as a precursor to further inquiry [25].

Our interviewees may have been more open-minded or optimistic compared to other stakeholders, as participants may have been more curious, interested individuals. We did not independently verify the veracity of information provided by participants; the results reflect their best understanding.

3. Results and Discussion

The following section presents what was learned from our interviews and group discussions. Participants' overall perspectives about supplying poplar biomass for a biorefinery (Table 2) are presented first. These thoughts on feasibility apply across the different applications, whether poplar is grown for agricultural, wastewater management, or floodplain management purposes. Quotes and discussion are inserted throughout this section. Quotes were selected for illustrative purposes and are not attributed to specific stakeholder categories because we often heard similar sentiments expressed across groups. We edited quotes for brevity when it was possible to do so without losing meaning.

Table 2. Summary of participants' thoughts on general benefits and concerns about the development of a poplar-based bioproducts industry in southwestern Washington, USA.

Benefits	Concerns
Could help the struggling agriculture community	Will this poplar-based industry actually "pencil out"
Faster turn-around than other tree crops	Can damage from wildlife be prevented
Could be easier to manage than alternative agriculture options	Will harvesting equipment be available
Could work on wet, marginal land	Who will make the upfront investment
Comparatively low soil disturbance	What is coming in and going out of the biorefinery

Following the overview, we detail specific results for poplar grown for traditional agricultural, wastewater management, and floodplain management. Results for each application are presented, with example quotes in three tables. Following each table, a discussion is presented on what was learned from participants about local context, opportunities, challenges, and questions.

3.1. Overall Perspectives on Supplying Poplar Biomass

The first reaction of many stakeholders was to tell us that the region has tried in the past to make money growing poplar and it did not work out for them. About 15 years ago, farmers planted poplar in anticipation of highly-profitable markets (e.g., pulp, sawlogs) that never emerged. Stakeholders questioned how this proposed poplar industry would be different: *"You know . . . poplar is one of these things that won't go away. We've been doing poplar off-and-on for 30 years in the area, and unfortunately it's always ended up being a bust, a loser."*

However, stakeholders also said they would be interested in growing poplar if they knew they could make money doing so. The primary concern was whether the poplar-based industry "penciled out": *"I think it would be a very easy area to get people to convert whatever they have going if you could show them that they could make money."*

People acknowledged that poplar grew well in the area and that a new crop market could be very helpful for the agricultural community. Short rotation poplar was appealing as a crop because it:

- has a fast turn-around for a tree crop (3 years)

"I think [short rotation poplar] would appeal to some people . . . because the poplars before . . . they were eight years, nine years, it was a really long timeline before you 'got your payout'."

- requires less labor and input than row crops and livestock production

"Once that crop is in the ground, you have very little requirement for cultivation or no requirement for cultivation...So something that could be more planted and left just like an annual forage crop, hay or alfalfa. Those kinds of things could have a lot of possibilities."

- might provide income on marginal, wet farmland

“There’s lots of marginal areas in Lewis County, and it really can’t crop anything. I don’t know if you can even pasture it. It’s just so wet . . . and those are the areas something like that’d work.”

- does not tear up the soil (after initial planting)

“I really like this idea where you’re not even taking it out of the ground. Especially from a land standpoint cause you’re not destroying the soil, the ecosystem as far as the soil goes and everything.”

Wildlife damage from elk, deer, and beaver is a major consideration. Some former poplar growers experienced severe devastation: “[The elk and deer] ate 30,000 trees of 60,000 in the first year.” While elk fences may be an option, stakeholders commented that fences are an additional expense and will not hold up in areas with regular flooding: “Winter’s typically when we got our damage [in the poplar fields]. Any fence is going to get washed out with flooding.” Elk damage is a concern for agriculture more broadly, as farmers are also having trouble elsewhere in the PNW [27].

Participants wanted to know about the availability of harvest equipment. There is not equipment in the region currently and purchasing would be costly: “Somebody’s got to be financing it. . . . you get a bunch of people to plant it and then nobody’s got the money to buy the harvester, then you got a problem.” However, one person we spoke to saw this as an additional business opportunity. They felt that there would be interest in starting a harvesting contracting company: “I know industrial people here that would just clamor to get an opportunity to buy the equipment that could do the harvesting and that’s a whole industry, just harvesting.”

Many stakeholders seemed to feel that the biggest hurdle would be securing the initial investments necessary to start the industry: “. . . seems like it would take a major initial investment and whether that has any validity to it at this point . . . I certainly don’t know. I don’t know if anyone knows.” Although there are investors interested in economic development, they would need to be sure of a return: “This county’s very, very conservative. You’ve got to show them the wares before they’ll invest a nickel of their money.” Failures from past ventures make growers wary of poplar, and most would first need to see money invested in poplar-related infrastructure. That said, an agricultural consultant noted that farming is always a risky venture: “Farmers are gamblers. They’re the biggest gamblers in the world. Because you have not only weather, you’ve got markets and the government and all of those things can affect what happens to your crops.”

The stakeholders we spoke to did not think that poplar farming would influence the general public, or if it did, the reception would be positive. They informed us that the region is familiar with tree farms (e.g., Christmas tree farms) and has a long history of forestry and farming. They felt the biorefinery would be of greater concern to the local community. Poplar biomass can be made into a variety of bioproducts, and we did not specify a particular output for the biorefinery during our interviews and discussions. Participants felt that the local community would want to know what the end product is, as well as what is transported in-and-off the site, what by-products or wastes are generated, and any impacts on air or water quality: “They’re going to want to know what you’re bringing into the site, what you’re producing on the site, and what you’re taking off the site.” A participant shared with us that public health is a priority in their particular community: “I think it comes down to what are you doing to the community. As far as putting it in the air and the water, that’s what they are concerned about.” These are common concerns for industrial-scale biomass facilities expressed by local communities [28,29]. In addition, perceptions about biorefinery impacts could affect growers’ decisions: “. . . certain people won’t grow things if it’s going to create something that could be harmful.”

3.2. Poplar and Agriculture

Poplar could be an alternative crop available to farmers to support their livelihood. We asked stakeholders about: (a) the state of local agriculture, (b) where participants saw opportunities and challenges, and (c) the questions they would need answered. A summary of the main points and associated quotes are presented in Table 3, followed by a discussion of the results.

Table 3. Summary and quotes related to the potential for poplar farming to contribute to agriculture in southwestern Washington, from participant stakeholders in agriculture and natural resources.

Local Context	Quotes about Poplar and Agriculture
(a) Agriculture is in trouble (hard to make a living; expanding development pressures)	(a) <i>“Many of the folks that I knew and their families that farmed for a living twenty years ago . . . farming is [now] secondary to some other line of work, the day to day”</i>
(b) Integral to region’s rural history and character	(a) <i>“One thing that Pierce County has been inundated with are the increase [sic] in the number of warehouses and distribution centers.”</i>
(c) Past poplar ventures (for pulp/sawlogs) failed because of a lack of markets	(b) <i>“Like the small community feel . . . the amount of land one person can have to themselves, agriculture opportunities, and closeness to family.”</i>
	(c) <i>“[Poplar] isn’t news. This was tried on the harbor, there’s a half a dozen different places in Grays Harbor that I know of, and it didn’t prove profitable for the people.”</i>
Opportunities	
(a) There’s a need for a profitable crop and local markets	(a) <i>“ . . . because of the loss of infrastructure and the basically desperate nature of the farmers in this area, they’d be open to a crop if it pencils because they’re getting so limited...I mean we’re down to forage. It’s the primary crop here and you know there’s a limit to how much forage you can move.”</i>
Challenges	
(a) Need payment assurance	(a) <i>“My expenses would have to be covered. Because it’s not cheap.”</i>
(b) Could clog tile lines	(b) <i>“Our cottonwood trees were actually getting down in the tile drains and filling them completely up with their roots. So we had to put in some open ditches to continue to drain the field.”</i>
(c) Could present complications with irrigation rights	(c) <i>“What they do on the water rights is they’ll say you get two acre feet per acre, but if you grow a crop that only takes one acre feet per acre, you didn’t keep your records and they say that’s your water right.”</i>
(d) Some hayland/pasture is needed for livestock and horses	(d) <i>“I probably wouldn’t want to plant poplar on my little bottom land. Although, wouldn’t be a bad idea. It’s just that I have horses, so they don’t eat poplar, they eat grass.”</i>
Questions	
(a) When would market saturation happen?	(a) <i>“ . . . a lot of these people come off with something new and bright and the earlier adopters will make a little bit of money but once it saturates so fast, that the price falls out and there’s no money to be made out of it.”</i>
(b) How many acres would an individual need?	(b) <i>“How many acres of trees would you estimate you would need to make a profit [as an individual]? The average farm in Lewis County is 49 acres. Most of the farm area you’ve got is very small acreage.”</i>

3.2.1. Poplar and Agriculture: Local Context

Resident stakeholders expressed enjoyment of the small-town, slow-paced lifestyle and liked outdoor recreational activities, such as hiking, fishing, and boating (Figure 3). However, many participants said that the rural areas are economically depressed, suffering from poverty, downscaled industries, and unemployment. Lewis, Grays Harbor, Mason, and Wahkiakum Counties ranked in the bottom quarter of Washington State counties for per capita personal income in 2015 [30]. Participants said the agricultural sector, traditionally a primary source of livelihood in the region and part of the local character, has been hit hard with challenges (e.g., lack of infrastructure/markets, catastrophic flooding, housing development, and aging landowners). We learned from the stakeholders that a local

frozen foods company processing peas and corn recently decided not to take produce from western Washington, leaving growers struggling to figure out what to do instead: “*This year we’ve been told the cannery isn’t going to take any crops on the west side [of WA state]. Our crop growers are going, ‘what are we going to grow?’ I mean we can’t grow the corn, the sweet corn, the peas, or the beans, which have all been harvested here before.*” Participants also mentioned that other parts of our study region are increasing warehouse and housing development on former agricultural land, particularly Pierce County and along I-5.



Figure 3. A rural landscape in Lewis County in southern Washington, USA.

3.2.2. Poplar and Agriculture: Opportunities

If a poplar market emerged, it could be a useful aid for the struggling local agricultural community. Farming consultants and partners said there are not many options when it comes to selecting a profitable crop. Participants said the farmland is less than ideal, there is a lack of agricultural infrastructure and markets, and existing markets are saturated. Additionally, interviewees from or working with the agricultural community told us that many farmers are of retirement age without willing heirs to take over the family business, and young people cannot afford to buy those farms. These challenges facing agriculture are not unique to southwestern WA. An aging farm population and dependence on outside income is a national trend [31].

When asked if people would consider poplar if they could make money doing it, people indicated that they would be interested. As a participant noted, the region grew poplar before and would again if it made financial sense. Agricultural and natural resources professionals did not think it would be difficult to find enough suitable land and secure willing growers if poplar were profitable. This suggests that a clear business model would facilitate further discussion with landowners and that there is not strong opposition to growing poplar based on other factors. In contrast, Warren et al. [20] found that farmers in southwest Scotland felt short rotation woody crops did not fit with their identity, lifestyle, farming culture, and prioritization of food production. The difference in response in our study from Warren et al.’s may be a result of cultural differences, or it could be a further indicator of the “*desperate nature*” of farmers in southwestern Washington.

Given the difficulties facing agriculture our participants laid out, we see a number of ways a poplar biorefinery could present an opportunity to boost the local agriculture community. The biorefinery would create a new market and provide farmers with another cropping opportunity, even on marginal

farmland. With the introduction of a potentially growing market, there could be openings for new people to get into agriculture. As a comparatively low-maintenance crop, poplar may also be appealing to older farmers.

3.2.3. Poplar and Agriculture: Challenges

As with other studies of willingness to adopt bioenergy crops [17,32,33], profit is a leading decision driver. A primary challenge would be providing reasonable assurance that poplar would be profitable. This could involve contracts between the farmer and the biorefinery [32], which a lending institute for the facility is likely to require.

Farmers with tile lines may need to switch to different draining methods for their fields. A participant from a local conservation district shared a story about how poplar trees clogged a field's tile lines on a property they worked with and alternative means of drainage were needed. Worries about tile lines could preclude some landowners from growing poplar: *"A lot of these tile line places are going to be like, we don't want to put those in, they'll break our tile lines."*

While flooding is a concern for farmland during the winter months, the region faces droughts during the summer months. Participants explained that irrigation rights are valuable property assets because no new water rights are allowed and existing rights can be lost if "beneficial use" is not demonstrated at least once every five years: *"[Department of Ecology regulators] always try to find a way to take some away. It's really hard for people to prove they've used their whole water right."* Those landowners who have irrigation water rights would need to think about how to maintain that value. The poplar trees may not require irrigation, and irrigation rights could be lost if not utilized. Irrigation can boost poplar yields, but it would be up to the landowner to determine if this is a good use of their water right and if they feel confident it would satisfy requirements for "beneficial use." A stakeholder mentioned that a water trust is an option, or property owners could choose to sell their water rights.

Not everyone in the agricultural community will be interested in poplar. Some hay and pasture is needed to support livestock and horses in the region. For example, we spoke to a retired landowner who runs a small beef operation and a resident who owns horses for personal enjoyment. In other cases, a participant explained that land has been pasture for decades because it is easy to maintain and expensive to come back to after using the land for crops: *"What happens is it's very expensive to work up a field and plant crops and then turn it back into pasture . . . a lot of farmers are letting crops stay in grass for years and years. I was a kid here, and I know pastures that have never been worked up."*

3.2.4. Poplar and Agriculture: Questions

There are concerns that need to be addressed, beyond needing assurance that poplar will be profitable. A lot of the farms in the study region are smaller parcels (<50 acres) [34]. Stakeholders wanted to know, from an individual's perspective, how much land a farmer needs to grow poplar profitably. On the other extreme, potential growers want to know at what point the market would become saturated from too much poplar farming. Southwestern WA has experiences with market saturation problems, for example the current glut of cranberries [35].

3.3. Ecosystem Services: Wastewater Management

Poplar can be a tool for wastewater management by evapotranspiring away reuse water, utilizing biosolids, or further treating wastewater for nutrients and contaminants [10]. We used the interviews and group discussions to learn from stakeholders about: (a) the current use of poplar for wastewater in the study region, (b) where participants saw opportunities and challenges for additional wastewater poplar plantations, and (c) the questions that need to be addressed. A summary of the main points and associated quotes are presented in Table 4, followed by a discussion of the results.

Table 4. Summary and quotes related to the potential for poplar to provide ecosystem services for wastewater management in southwestern Washington, from participant stakeholders in agriculture and natural resources.

Local Context	Quotes about Poplar and Wastewater
(a) Economical way to meet regulations	(a) <i>"It was either [the poplar plantation or] remove all of [City of Chehalis's] water during the summertime some point well north of Centralia, which would have cost way too much money."</i>
(b) Permits and irrigation are burdensome	(b) <i>"[There is] a permit for going out to the tree farm and one for going to the river. And going to the river is a lot easier to meet."</i>
(c) Provides other ecosystem services	(c) <i>"Aesthetically it's a draw . . . a lot of people want to take their wedding pictures out there."</i>
Opportunities	
(a) People like this idea	(a) <i>"I like the wastewater one. I think that's a terrific idea."</i>
(b) Treatment plant retains the reuse water rights	(b) <i>" . . . we reserve the water rights. So [if] some industry wants to potentially use reclaimed water, it's ours, we can do what we want with it."</i>
(c) Water stays in the immediate watershed	(c) <i>"We're keeping the water in our local basin."</i>
(d) Extracting excess nitrogen	(d) <i>" . . . the groundwater is actually improving . . . Before it was a farm, potentially mismanaged, nitrogen leaching through the soil."</i>
(e) Potential biosolids applications	(e) <i>" . . . stigma from the general public is they don't want [biosolids] to go on [food] crops . . . whereas with trees, nobody cares."</i>
(f) Two other cities expressed interested	(e,f) <i>"We now ship our biosolids during the wet months at a high cost."</i> (f) <i>"We may need to be looking at possibly not discharging our effluent to the [river] in a few months of the year."</i>
Challenges	
(a) Plants unlikely to consider it unless necessary	(a) <i>"I don't know about the other treatment plants being forced out [of the river]. We're kinda one of the few in western Washington."</i>
(b) Plant is responsible for groundwater monitoring	(b) <i>"I'm not going to want to give [reuse water] to farmers because the city's responsible for the ultimate disposal or reuse."</i>
(c) Economic concerns	(c) <i>"One concern might be the cost for start-up to get the farm rolling with poplar trees."</i>
(d) Regulations could shift to river water quantity over quality.	(d) <i>" . . . hoping sometime in the future they'll say you can put your water back in the river. At that time the plantation just becomes a bunch of trees."</i>
Questions	
(a) Can coppice poplar suck up enough reuse water?	(a) <i>"The question is would that poplar, because most of those you see grow into big trees, they don't cut them every three years, would it still work for wastewater management?"</i>
(b) Can overhead irrigation (rather than ground sprinklers) work?	(b) <i>"Irrigation is very labor intensive. [If] the trees wouldn't get that high, 30 feet at the most, and we could put some type of large irrigation pivot, it would be a lot easier to irrigate."</i>

3.3.1. Poplar and Wastewater: Local Context

As previously mentioned, the City of Chehalis is using a 176-acre poplar tree plantation to meet total maximum daily load (TMDL) restrictions placed by the WA Department of Ecology for the protection of river water quality (Figure 4). When the river drops below 1000 cubic feet per second, which normally happens between April and November, the reclamation facility cannot discharge to the Chehalis River. Instead, the water is used to irrigate the poplar trees.



Figure 4. The City of Chehalis Poplar Plantation, where the trees are irrigated with reuse water during the dry months, has other environmental benefits like wildlife habitat.

A person closely tied to the wastewater treatment facility said that developing the poplar tree farm was the right choice for the City of Chehalis: “... *the poplar tree plantation was the cheapest and the most beneficial option that we chose and it's still a good decision today.*” They informed us that the farm allows Chehalis to meet the TMDL restrictions without having to pump the water far from the treatment plant (which was the alternative). Also, they noted that the farm is an aesthetic draw, carbon sink, nutrient extractor, and wildlife habitat.

However, there are challenges to running the poplar plantation. The participant shared that the poplars are destined for the sawlog market but are still not big enough to sell despite being older than they thought they would need to be. The trees are now fifteen years old, pushing the plantation into a forestry rather than agricultural land-use and thus requiring different permitting. Additionally, the participant noted that permit for applying reuse water to the trees is more burdensome than the permit to discharge to the river, and the sprinkler system (Figure 5) needs constant maintenance to deal with coyote damage and clogging.



Figure 5. One of the 20,000 sprinkler heads used to irrigate the Chehalis Poplar Tree Plantation with reuse water.

3.3.2. Poplar and Wastewater: Opportunities, Challenges, and Questions

From a social perspective, the idea of combining wastewater and poplar farming was well received. However, those participants most familiar with the concept of using poplar to process reuse water questioned the ability of short rotation coppice poplar to take up enough water to get the job done. At this time, it is unknown whether a coppiced poplar farm could meet the needs of the wastewater treatment plant, but preliminary research at AHB's demonstration site in Hayden, Idaho showed similar average irrigation rates between coppiced and 20+ year-old poplar [36].

A participant noted that a potential benefit of using short rotation coppice poplar over using longer-rotation poplar is that the trees will be shorter, and overhead irrigation might be a possibility. They felt overhead irrigation could avoid the maintenance issues associated with a ground-level sprinkler system, like the coyote-chewing damage faced by the Chehalis plantation. Research would be needed to evaluate this idea. Based on conversations with outside experts, potential concerns about overhead irrigation include impacts on tree health and technical feasibility, but overhead irrigation may also facilitate a good amount of direct evaporation into the air. We should also note that some of the characteristics of the current longer-rotation plantation (e.g., aesthetics) would be different under a short rotation coppice system.

Although the Chehalis Poplar Plantation does not apply biosolids to their poplar trees, we did speak to a landowner who currently uses biosolids on his crops and would consider applying biosolids if they grew poplar. When prompted to think about biosolids, participants noted that some members of the public are adamantly opposed to applying biosolids to food crops and thought that using biosolids on a biomass crop like poplar might be more acceptable. One city told us they ship their biosolids to Eastern Washington part of the year at a high cost and would consider an alternative like operating a poplar farm on their land. There are examples of other wastewater treatment plants in the Pacific Northwest applying biosolids to poplar, like the Biocycle Farm in Eugene/Springfield, OR [37]. Another treatment plant asked whether there would be leftover poplar chips, and if so, whether they could be used in their biosolids compost operation.

A wastewater professional informed us that discharging cleaned wastewater to rivers or groundwater is easier to permit and cheaper to do than irrigating a poplar farm. Therefore, one challenge may be finding enough wastewater treatment plants interested in growing poplar to meet any significant portion of a biorefinery's poplar demand. That said, we also heard from a city that recently learned they may not be able to discharge their water into the river in the future, similar to the restrictions imposed on the City of Chehalis that lead to the establishment of the Chehalis Poplar Tree Plantation. Furthermore, although not mentioned by the participants, poplar may be able to remove chemical contaminants, like pharmaceuticals, that wastewater treatment does not capture [9,10].

3.4. Ecosystem Services: Floodplain Management

Poplars are adapted to live in riparian and flood-prone areas. Poplar may serve as flood mitigation tool by increasing landscape roughness and providing a more suitable crop for farmers in flood prone areas. An EPA review from 1999 predicted there would be an increase in hybrid poplar cultivation in degraded floodplain to supplement native hardwoods and to treat nutrient runoff [38]. A watershed management project in Minnesota proposed using hybrid poplar plantings to improve water quality, reduce excess stream flows, and provide farmers with a profitable crop [39]. In 2005, a case study explored whether a poplar riparian buffer could be economically sustainable for blueberry farmers in western Washington [40].

We used the interviews and group discussions to learn from stakeholders about: (a) local flooding issues and planning efforts, (b) where participants saw opportunities and challenges for poplars in the floodplain, and (c) the questions that need to be addressed. A summary of the main points and associated quotes are presented in Table 5, followed by a discussion of the results.

Table 5. Summary and quotes related to the potential for poplar to provide ecosystem services for floodplain management in flood-prone southwestern Washington, from participant stakeholders in agriculture and natural resources.

Local Context	Quotes about Poplar and Floodplains
(a) Floods are frequent and can be devastating	(a) <i>"You know it's a big deal when you shut down I-5 twice a decade. It cost hundreds of millions of dollars 'cause north-south traffic is stopped."</i>
(b) Restoring native riparian habitat for salmon conservation	(b,c) <i>"... to protect the habitat and to do restoration at the same time as considering these flood damage reduction actions because obviously they both have an effect on the floodplain. It's an effort to move both of those pieces of this integrated strategy forward at the same time."</i>
(c) Massive collaborative planning strategy underway	
(d) Concerns among landowners about losing private property rights	(d) <i>"There's a lot of uncertainty or suspicion about regulations and uses of land minimizing the tax base in the community."</i>
Opportunities	
(a) Great if people could make money off their land while decreasing flood risk	(a) <i>"... doing something that would still give people use of their land that included the floodplain I think would be pretty favorably looked at."</i>
(b) Could have native riparian buffers and poplar farms beyond that	(b) <i>"... restoring the floodplain forest and then...we could put a poplar plantation on someone's farmland in area where water's going to be coming out of the river channel, and that would effectively slow it down."</i>
Challenges	
(a) Don't want non-natives near the river	(a) <i>"... I think, might be a little bit of a difficult sell in the sense that you're talking about hybrid, not natural species. Most of the folks that are involved in riparian stabilization are certainly going to be a little bit leery of using non-natives."</i>
(b) Could be a considered a risk to property rights, if poplar farms someday become regulated as buffer	(b) <i>"Okay, so we make this agreement, and I put some investment into planting [poplar]. And then the rules come along and they change and then I'm just out of another investment ... it gets people a little uptight. There's a lot of private properties right advocates from this area for that very reason."</i>
(c) Harvest window would be limited to when the ground was dry enough for equipment	(c) <i>"You're not going to harvest in the winter most of the ground that's suitable [for poplar]."</i>
Questions	
(a) How much inundation (frequency, depth, duration) can poplar handle?	(a) <i>"How well do these trees deal with flood? 'Cause they could easily be flooded 6 to 8 feet deep during a good storm, and I just don't know how well they deal with that."</i>
(b) Would hybrid poplar crossbreed with native poplars?	(b) <i>"We're spending literally millions of dollars getting rid of a variety of non-native and invasive species. If it crossbreeds with the native species creating something that's different, you could very easily be creating a new, non-native invasive species along our rivers."</i>
(c) Would hybrid poplar drain low-flow streams in summer?	(c) <i>"The low flows in the summer and early fall in this basin are a huge issue. And I know that cottonwood, from what I understand at least, take a lot of water. How's that gonna affect instream flows in the summer or would it?"</i>

3.4.1. Poplar and Floodplains: Local Context

A challenge in the study area is how to simultaneously manage the Chehalis Basin for flood mitigation and aquatic species protection [41]. Flood events in recent decades have severely impacted the cities of Centralia and Chehalis and forced closures of Interstate 5 (the highway linking Vancouver, British Columbia, Canada, Seattle, WA and Portland, OR). At the same time, there is need for aquatic species (e.g., chinook salmon) conservation efforts. Proposed actions for the Chehalis Basin could change land-use practices in the floodplain, where much of the farmland is located (Figure 6). Balancing salmon conservation practices and agricultural land-use impacts is a long-standing issue in western Washington [42]. Conservation requires willing landowners, and stakeholders shared that landowners in the area are wary of potential threats to private property rights.

Another element of the Chehalis Basin planning efforts is a proposal to build a dam. We expected to hear the proposed dam brought up during our discussions, as the dam is generating controversy in the region [43]. Tribal opposition was a major driver of exploring alternative or concurrent strategies for protecting aquatic species and restoring native habitat [44]. Although we did occasionally hear about the dam from stakeholders (e.g., *"... they're proposing to build a dam, and who in 2018 ever thought that would be around, but it is because of the flood problems we have on the river."*), stakeholders seemed to be focused on efforts to restore native riparian buffers. This may be an artifact of the participant sample including many people connected to habitat restoration planning.



Figure 6. Lincoln Creek (left), part of the Chehalis Basin, runs through an agricultural property, and floods the fields during the winter. The Conservation Reserve Easement Program (CREP) offers financial assistance to landowners for the planting of native riparian buffers, like this planting near Lincoln Creek (right).

3.4.2. Poplar and Floodplains: Opportunities, Challenges, and Questions

Participants shared regulatory and ecological concerns about hybrid poplar because it is non-native. Certain regulations prohibit non-native trees in riparian restoration projects. From an ecological perspective, participants questioned whether short rotation hybrid poplar could support ecosystem functions in riparian areas (food for aquatic species, habitat from downed wood, erosion control, shading) and wanted to know if the hybrid poplar would crossbreed with native populations of poplar. In addition, there were concerns about whether poplar would reduce stream flows in the summer months.

Concerns about crossbreeding may be unwarranted for two- to three-year harvest cycles because the trees can be harvested before sexual maturity. Alternatively, the trees could be genetically modified not to flower [45]. Poplar trees can reproduce vegetatively (i.e., sprout from broken branches and other tree material), so there is some risk of escape beyond plantations. Native cottonwood could be used instead of hybrid poplar, but these trees will have lower yields.

Many of the points we heard from the stakeholders in our study region were also reflected upon in the 1999 EPA review [38]. For example, farmers could plant the trees just beyond critical riparian habitat as a cost-effective way to improve the degraded floodplain, but there was fear of crossbreeding with native cottonwood and depletion of water availability. When the 1999 EPA report was written, there were few studies specifically designed to address these environmental issues. This remains largely true twenty years later.

Another challenge of producing poplar on flood-prone farmland is that the harvesting window would be limited to times when the ground was dry enough to run equipment. This concern was raised by a farmer, who had seen video of short rotation harvest elsewhere in the country happening when the leaves were off and the ground was frozen. The AHB project encountered similar challenges at its demonstration sites in western Oregon and Washington, where muddy ground in the winter forced harvest delays. While leaves can introduce unwanted heterogeneity to the poplar chips and reduce sugar availability [46], leaves may be unavoidable if harvest must occur when the ground has dried out in the late spring. However, technology to separate leaves from the biomass is under development [47]. If the biorefinery needed a continuous flow of materials, some drier ground would need to be converted, an alternative source of biomass (like hardwood sawmill residue) could be used, or storage methods would need to be developed.

Short-rotation hybrid poplar may also serve a strategic purpose for flood mitigation: *“generally speaking, a tree crop is going to serve useful functions during flood events.”* We spoke with a consultant who is thinking about how hybrid poplar might be able to provide roughness that slows down floodwaters

in a reconnected floodplain. Although the participants did not emphasize the proposed dam during discussions, we believe that poplar farms may offer an alternative that is a compromise between maintaining profitable use of private land along the river and providing more riparian ecosystem services than the agricultural land use currently in place.

However, stakeholders want to know how much inundation poplar can handle. Although poplar is more tolerant of wet (and dry) conditions than many other trees and crops, stressful growing environments limit the amount of biomass that can be produced. Research is needed to understand how well poplar would be able to produce biomass in very wet ground.

Another stakeholder saw a potential risk to landowner property rights if poplar is part of a floodplain strategy—it could someday be considered part of a larger agricultural buffer and be restricted from harvest. This participant told us that forest landowners suffered when forest practice rules changed, forcing them to remove part of their land from production. Farm landowners in Lewis County are not currently required to have buffers, but regulations could change as Chehalis Basin management progresses.

Circumstances may differ across counties in the study region. One participant said that the restrictions on floodplain development are more stringent in Thurston and Pierce Counties compared to Lewis and Grays Harbor Counties. Given strict limitations in Thurston/Pierce, they thought poplar may be appealing as a land-use option, while economic development in Lewis County (specifically Centralia and Chehalis urban growth areas) may preclude poplar in those floodplains.

4. Recommendations

Participants suggested ways of framing the potential poplar-based bioeconomy that would present the industry in a positive light. One person proposed saying “cellulosic biomass” rather than starting with poplar, due to experience with past poplar market failures: *“I wouldn’t run out with poplar on the top line of my banner . . . [but] this is a timber county. So if you say, ‘hey we’re refining fuels from cellulosic materials,’ they’ve heard that before.”* Others recommended focusing on how producing poplar could be a desirable choice for private landowners and the community, rather than a top-down, mandated change for the floodplain: *“ . . . what we’ve found in other areas working in the floodplain is that people’s first reaction is, ‘It’s my land, and I don’t want anybody telling me what I can and can’t do with it’ . . . They don’t want to just give it away, but, if there’s a better use for that land, that’s usually [the] kind of theme that resonates with them.”*

Another area where framing is important is related to poplar and the floodplain. An environmental consultant advised being clear about what part of the floodplain is being discussed. A different stakeholder observed: *“There’s a difference between riparian and floodplain, especially in the lower stretch of the river. I wouldn’t market [hybrid poplar] so much as for a direct buffer river habitat benefit, but if you’re talking about ‘hey, here’s a crop of value’ . . . It’s not like peas or wheat are sitting in there because of the environment it’s in.”* They felt that talking about poplar as a riparian buffer would limit the potential because of concerns over ecological restoration. However, poplar farming in the non-riparian floodplain areas may be more acceptable and may actually improve the ability for conservation and restoration by improving the overall economy.

Potential strategies for addressing some of the major challenges presented in this paper are listed in Table 6.

In addition to addressing the challenges, there are a number of remaining knowledge gaps. We recommend conducting a thorough literature review tailored to the specific questions posed by the stakeholders. Education materials could be developed from this review and tailored to the situation in southwestern Washington. We also recommend eliciting opinions on the bioeconomy and specific end products, combined with public outreach and education. Bioenergy, particularly corn ethanol, is a contentious issue [32,48], and it is important to acknowledge the role emotions and terminology play in stakeholders’ acceptance of a potential bioeconomy [49,50].

Table 6. Strategies for addressing challenges to developing a poplar-based bioeconomy in southwestern WA, USA.

Challenges	Ways Forward
Damage from wildlife	(1) Test if short rotation coppice poplar experiences the same level of damage (2) Explore fencing options, particularly in flood-prone areas (3) Develop unpalatable varieties or repellents
Harvest operations	(1) Establish a framework for a harvesting cooperative (2) Develop a harvesting company business model (3) Explore chip storage or alternative feedstock options to supply the biorefinery during times when the ground is too wet for the harvester
Initial investments	(1) Develop a detailed business prospectus for potential investors and economic development stakeholders (2) Collaborate with Lewis County Economic Development Council, TransAlta, policy makers, potential investors, and private industry (3) Demonstrate a small-scale refinery using existing poplar farms (4) Explore carbon markets
Biorefinery concerns	(1) Be upfront and clear about the biorefinery's end product and what it is used for (2) Explain potential community benefits and impacts using examples of biorefineries elsewhere in the PNW or US. (e.g., biodiesel and ethanol plants)
Wastewater irrigation	(1) Establish a test site for overhead irrigation of short rotation coppice poplar to see how much recycled water could be processed by the trees and whether applying recycled water to the leaves impacts tree health

Further development toward a poplar-based bioindustry will require more community involvement. Our preliminary exploration of opportunities, barriers, and values only accounts for a subset of the natural resources and agricultural stakeholders. The next step in stakeholder participation would be reaching a wider diversity of people and evaluating the level of concrete interest in pursuing the industry (rather than theoretical feasibility). The latter will require sharing available economic information and more detailed growing guidance.

5. Conclusions

Given a convincing business model, agricultural and natural resources professionals believe it would be straightforward to find suitable land and secure willing poplar growers. Unsurprisingly, economics is the bottom line: who would make the initial investment, and would growers make money. According to participants, local agriculture is in desperate need of a boost, such as a new, lucrative crop market. The participants did not bring up concerns about short rotation poplar in relation to their identity, lifestyle, farming culture, or opinions about food production, unlike in a study mentioned earlier [20]. The region has experience growing poplar, albeit for a different industry, on longer harvest cycles, and without turning a profit.

Hybrid poplar would not be used as stream buffers, as non-natives are not desired or allowed for riparian restoration. Poplar farming could also displace some hay/pasture currently used to support livestock and horses, and could run into concerns about water scarcity, water rights, and drainage tile lines. Technical questions remain, such as how much flooding poplars can handle and how to prevent elk damage.

Overall, if economic objectives can be met, participants saw chances for win-win situations where landowners could profit on otherwise low-value agriculture/pasture land and achieve ecosystem services for wastewater or floodplain management. For example, a landscape strategy partnering native riparian buffers with adjacent poplar fields in wet bottomlands could potentially invigorate the agricultural community, protect landowners from flooding, and conserve fish habitat. However,

elk may cause issues without a fence, and a fence may not work in the floodplain. Landowners would also need to be reasonably assured that their poplar plantation could not later fall under riparian conservation regulation and be lost as a private property asset.

Based on this preliminary stakeholder assessment, it seems like poplar could fit the values and meet needs of southwestern Washington, but a number of concerns and unknowns would have to be resolved. There are opportunities for poplar as an ecosystem services provider that require scientific research to verify feasibility. Next steps could include establishing local experimental poplar plantations, developing a detailed business prospectus, producing educational material about the biorefinery, and discussing with a greater number and broader diversity of stakeholders.

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Appendix A. Methodological Details

The focus group was conducted during a Chehalis Basin Partnership meeting and lasted 90 min. Thirteen attendees (of an audience of 17—not counting the researchers) contributed to the focus group. Participants were a mix of representatives from government, non-profit, and private citizens, who shared a common interest: *To implement a management plan that will result in effective, economical, and equitable management of the water in the Chehalis Basin to sustain viable and healthy communities and habitat conditions necessary for native fish* (<http://chehalisbasinpartnership.org/>). We provided a brief presentation on the research project at the beginning of the meeting, and then facilitated an exchange of thoughts and questions based on topics similar to the interview guides. We also requested they fill out a short questionnaire about their personal opinions on their communities.

The group discussion took place during 20 min of a Lewis County Farm Bureau meeting. A brief presentation was followed by participants sharing initial reactions, concerns, and ideas. In addition to generating interesting information in-and-of itself, the meeting allowed us to connect with individuals directly connected to agriculture in the study region, including some people who had grown poplar trees in the past. For the short group discussion, we only transcribed the participants' comments, rather than the full dialog with the facilitator.

Follow-up interviews were conducted with interested participants from the two group discussions.

Appendix B. Background Information for Interviewees

This information was provided to interviewees to review prior to the interview as an email attachment or hardcopy given in-person. Figures are not captioned, as they were not captioned in the original document.

[Note: During the interviews, we discussed the different reasons for growing poplar using the term “scenarios”. However, these different reasons are not mutually exclusive (as the word “scenario”

may imply), and we envision a future consisting of all three applications (poplar for farm revenue, for wastewater treatment, and for floodplain management). Therefore, in this article we chose to call them “applications” instead of “scenarios”. In our conversations with participants, we explained that the “scenarios” were not mutually exclusive.]

Appendix B.1. Background: Growing Hybrid Poplar for Biomass

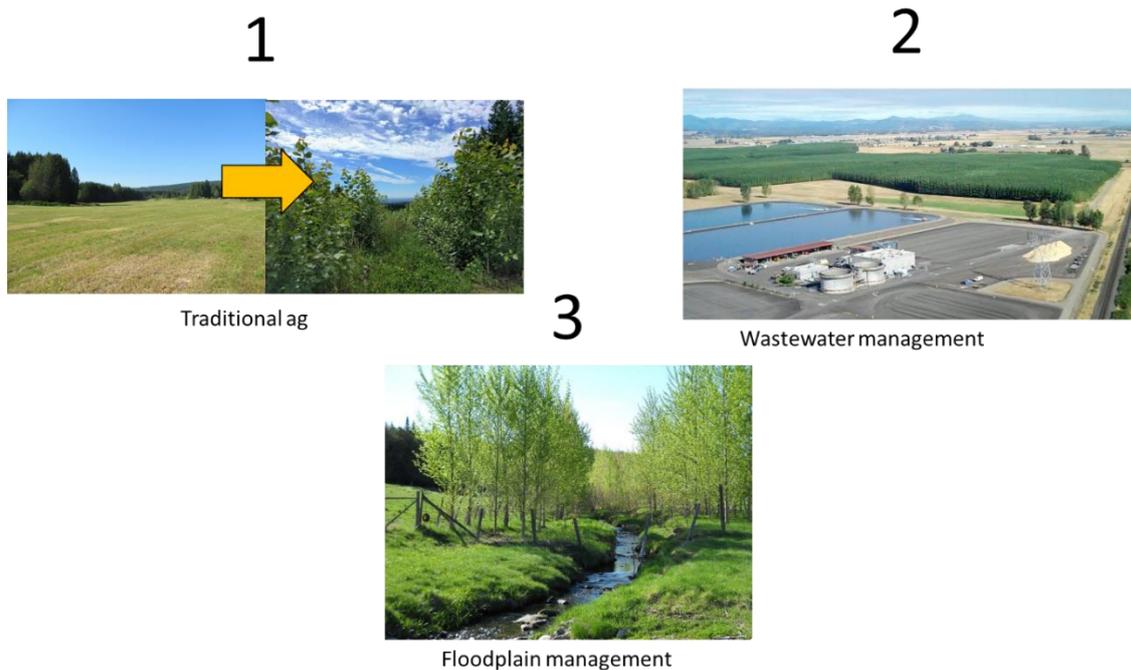
Poplars, a group of trees that includes black cottonwood, are the fastest growing trees in temperate regions. Hybrid poplars (crossbreeds of different types of poplar) are commonly found in nature and can also be created in a nursery. These hybrid poplar trees can produce lots of biomass and are adaptable to a wide range of sites. The trees resprout after harvest and can be cut on three-year cycles as a perennial agricultural crop. Hybrid poplar chips can be turned into bioproducts.



Appendix B.2. Introduction

Models have identified Lewis County and the surrounding area as having potential for a poplar-based chemical industry. Specifically, researchers are modeling the technical and economic feasibility of a hypothetical refinery in Centralia, WA, USA supplied by poplar grown within 100 km of the site. In all scenarios, we assume 34,500 acres of land is converted (equivalent to about 25% of existing pasture land).

- Scenario 1: Farmers convert pasture land (i.e., non-cropland, not hay) or cropland into hybrid poplar farms.
- Scenario 2: Wastewater treatment plants lease land for hybrid poplar farms.
- Scenario 3: Poplar farms or buffers are developed in the floodplain.



Appendix C. Interview Guide

Interviewers used this interview guide as a template to generate conversation with participants. The interviews were semi-structured, meaning that interviewers were free to explore ideas and ask additional questions based on the responses of interviewees. [See note in Appendix B about the use of the term “scenarios.”]

Appendix C.1. Background about Interviewee and Community (5 min)

- Question 1: To start out, I'd like to hear a bit about yourself and your community. Where do you live? [Prompt: Town, county? rural, suburban, or urban?]
- Question 2: How long have you lived in the area?
- Question 3: What do you like about living there? [If they have been there for a long time (10+ years), ask how things have changed. If they have been there for a shorter time, ask them to compare it to where they lived before this.]
- Question 4: What is your profession? OR Where do you work? OR Who do you work for?
- Question 5: What community or communities do you consider yourself a part of? [Prompt: How about at work? How about outside of work? What is your role in those communities?]
- Question 6: What projects are going on in the area that you're aware of? [Prompt: For example, development initiatives (new business, housing development, agricultural shifts) or problems to solve (flooding, income).]

Appendix C.2. Discussion about Poplar Farms (10 min)

Now we'd like to talk about growing poplar for biomass. Let's start by reviewing the background information. [Read through the information describing how poplar is grown and the reasons to use it to make renewable chemicals.] Do you have any clarification questions?

- Question 7: What is your initial reaction to the idea of converting land into poplar farms? [Prompt: positive or negative? questions, concerns? economic, social, aesthetic?]
- Question 8: How do you feel about tree farms versus other kinds of crops?
- Question 9: When you see an open, grassy field or pasture, what do you think about?

- Question 10: Are you familiar with the poplar farm in Chehalis? If so, what do you think about as you pass by it?

Appendix C.3. Discussion about Scenarios (25 min)

Now we'd like to talk about the different scenarios we sent to you earlier. [Read through the description of the three scenarios about where and how poplar might be grown if a biorefinery were built in Lewis County, WA, USA.] Do you have any clarification questions?

- Question 11: Is there a particular scenario that you would like to discuss first?
- Question 12: What is your initial reaction to the [Traditional ag, wastewater management, or floodplain] scenario?
- Question 13: What challenges or barriers?
- Question 14: What opportunities do you see?
- Question 15: How do you think this scenario might impact your community? [Prompt: What ecosystem services could this provide? What might be the risks?]
- Question 16: Are there any modifications you would recommend for this scenario?
- Question 17: Is there anything else you would like to add about this scenario?
- Repeat Q 12–17 for each scenario.
- Question 18: Is there an alternative scenario that you think is worth exploring?
- Question 19: Is there anything else you would like to add?

Appendix C.4. Recommendations for Other Participants

- Are there any individuals or organizations you recommend we contact?
- Are there particular perspectives that you think we should try to include?

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