

TECHNICAL ARTICLE

February 2023

Harvesting of Short Rotation Coppice Willow

Author: Dr Nana Afranaa Kwapong

Take home messages:

- Willow is harvested every three to four years depending on the plant growth. Harvesting is done during the dormant season in winter (mid-October to early March) after leaf fall and before bud break.
- Harvesting is the single largest cost component of willow biomass production accounting for about 32 60% of costs over the life cycle of the crop (20 plus years).
- There are multiple ways of harvesting willow including the whole stem, cut and chip, and bundle harvesting system.
- Efforts to reduce harvesting costs by improving the performance and reliability of the harvesters and chip collection system are essential for the profitability of willow production.

Intro:

Willow is a short rotation woody crop that rapidly produces large amounts of biomass. The harvested willow biomass can be processed into renewable energy, heat, and other products such as livestock and poultry beddings, biochemicals, bioplastics and many more. Willow is harvested in a three-to-four-year rotation cycle after establishment and can be harvested six to seven times before replanting and requires minimal crop maintenance between harvest.

Biomass Connect is funded by the:



Harvesting is the <u>single largest cost component of willow production</u>, accounting for about 32 - 60%of costs over the life cycle of the crop (20 plus years). As such there should be efforts aimed at <u>reducing</u> the harvest cost by having reliable high performing harvest systems to improve the harvesting efficiency and increase the profitability of willow biomass production.

Timing of willow harvest

Willow harvesting is ideally carried out on a three-to-four-year rotation cycle. The plants should be ready for harvesting three years after the first cutback (coppice) or four years after planting depending on the plant development. Harvesting can be delayed for a year or two if the growth of the plant was poor due to drought or competition from weeds, insects, or pests. Willow harvesting is ideally done during the dormant season in winter (mid-October to early March) after leaf fall and before bud break in early spring. Willow can be harvested with a few leaves on the plant, but this increases the moisture and ash content and the harvested plant biomass removed from the field deprives the <u>soil of carbon transfer</u> and nutrients recycled into the soil. Recommended <u>optimal condition for harvesting willow</u> is when the ground is frozen or covered with little or no snow, to avoid excessive loads on the soil together with the formation of deep furrows in the field by the harvesting machines. However, such optimal conditions are not always feasible under field conditions as the winter season has wet weather conditions and the ground condition is wet and soils susceptible to damage from heavy harvesting machinery.

Harvesting Systems

There are <u>various ways of harvesting willow involving either a single step or two-step method of</u> <u>harvesting</u>. With the single step, the willow crop is cut directly from the stump and chipped in one operation. While with the two-step harvesting, the willow crop is first cut, stored, and naturally air-dried before later chipping and processing into the desired end product. The willow plants can be harvested manually or mechanically depending on the level of automation and the type of machinery.

Manual harvesting

Manual harvesting involves the felling of the willow plants with a <u>chainsaw</u> or <u>brush cutter</u> and collecting the logs manually or with a tractor, followed by direct feeding of the logs into a chipper. Alternatively, the logs can be collected and stored and chipped later. Manual harvesting is labour

Biomass Connect is funded by the:

intensive requiring a minimum of two persons. Manual harvesting is best suited for harvesting willow on small scale plantations. Manual harvesting is less costly and an affordable option for small scale farmers who lack the resources to purchase expensive harvesting machinery. Manual harvesting is also used in situations where it is the sole available option when commercial operated machinery is not available when needed for harvesting. It is however less efficient and less productive when compared with the use of mechanical harvesters. A <u>report</u> indicated that, it takes on average 45 hours to manually harvest 1 hectare of willow containing about 18,000 plants. A <u>study</u> reported harvesting cost varying from ≤ 16.3 ha⁻¹ to ≤ 23.2 ha⁻¹, suggesting manual harvesting an affordable option for small scale farmers even though gross production rates is very low (0.10 - 0.11ha/h). Another <u>study</u> showed that manual harvesting exposes workers to noise, uncomfortable work postures, and high cardiovascular loads. This study suggested that motor manual harvesting operations should consider the <u>compatibility of equipment and operational conditions</u> to the workers undertaking such tasks.



Mechanical Harvesting

Mechanical harvesting is more economical when used for harvesting largescale willow plantations, where the large capacity of the machines can be fully utilized, and the high capital cost can be spread over large harvest volumes. <u>Studies</u> have shown that in order to increase profitability, it is necessary to have efficient machinery available with which high-quality wood chips can be produced at low cost and easily handled during storage and transport. Commercial harvesters and chip-collection services are provided by contractors to willow growers, and this comes at a high cost and the challenge of availability of machinery when needed. Different modified <u>forage harvesters</u> and corn choppers are used for harvesting and chipping willow.

Biomass Connect is funded by the:

There are also specialized machinery designed for harvesting willow. Harvesting systems for willow includes <u>whole stem harvesters</u>, <u>small and large single-pass cut-and-chip systems</u>, and <u>bundle</u> <u>systems</u>. These harvesting systems are either self-propelled or tractor pulled harvesters.

Whole stem harvest system

Whole stem harvesting involves the use of forest harvesters or chainsaws for felling willow plants. The cut stems are collected with a tractor or forwarder and transported from the field to a storage site for drying and chipping later or the harvested stems chipped and sent for immediate use in processing plants. Harvesting willow as <u>stems or in large pieces has the advantage of providing year-round supply</u> <u>of natural-dried willow stem</u> for fuel processing plants. A <u>study</u> showed that, storing willow as whole stems produces a lower moisture and ash content fuel.



Cut and chip harvest system

With the cut and chip harvester, the willow plants are harvested in a single operation and directly chipped and transported to the end user or storage site. The harvester either pulls its own trailer to collects the harvested material or use a tractor-trailer combination, which travels alongside the harvester and receives the chips blown from the harvester. To optimize efficiency, the harvester downtime should be reduced by keeping the harvester moving and harvesting the willow crop on a continuing basis, while the trailer continuously collect the chips moving the chips to the load staging

Biomass Connect is funded by the:



area or end user. The plantation design and staging area should be well laid out to facilitate machinery movement and turning at the end of the rows. A <u>study</u> showed that cut-and-chip harvesters were faster than the whole stem harvester, and the self-propelled harvester was faster than the tractor-pulled harvester. This study further showed that harvesting costs differed depending on the machinery used for harvesting. Chips produced from the cut and chip harvester however have high moisture content and may require further drying to reach lower moisture content for efficient thermal combustion into energy, which involves further handling cost and may cause emission problems and dry matter losses. Dry chips can attract higher pricing at the power plant than wet chips.



Cut and Bundle system

<u>Cutter-bundler harvesters</u> are used to cut and fell willow plants. The harvested stems are gathered as bundles that are loose or tied with wire or yarn. The bundled stems are stored and dried to reduce the moisture content before supply to processing plants and other end users. Studies have shown that the cut and bundle system compared with the cut and chip system, allows for efficiently reducing the moisture content of the willow biomass before chipping and a more cost-effective alternative.

Biomass Connect is funded by the:

Department for Energy Security & Net Zero

www.biomassconnect.org



Some considerations in deciding on the choice of harvesting system

In deciding on the method for harvesting willow, land managers and landowners should consider the following factors that influence the harvesting operations of willow and create a harvesting plan considering these factors.

- Willow species and variety: Different <u>species and varieties of willow</u> have different growth forms, branching pattern (upright or arching stem), number of stems, stem thickness, stem diameters and stem height. The diversity of willow in growth form and stem structure affects the ease of harvesting and logistics required for harvesting.
- Diameter of the willow stem: Willow plants should not be allowed to overgrow beyond four years before harvesting. <u>Overgrown stems</u> can cause inefficiencies in the harvesting machinery when they exceed the mechanical specifications of the harvesting machinery.
- Age of the willow plant: The annual biomass production begins to decline as the plant ages, as such it is best to harvest the willow plants every three to four years. A <u>study</u> showed that stem age influenced the initial biomass composition and found that two-year-old stems contained more extractives and three-year-old stems contained more structural sugars. Also, <u>heat production</u> <u>varied</u> with stem age which impacted the final biomass composition.

Biomass Connect is funded by the:

Department for Energy Security & Net Zero

www.biomassconnect.org

- *End product*: Depending on the end product whether chips, pellets, or whole stems, different machinery and harvesting methods will result in different end products.
- *Quality of the willow biomass*: The <u>quality of the harvested willow biomass</u> is influenced by characteristics such as ash, moisture, energy and elemental content, and particle size distribution.
- Availability of machinery: The availability of harvest machinery at farm or at least in the region where willow plantation is located is very important for the reduction of harvest costs.
- Condition of the soil: It is best to <u>harvest under dry or frozen ground conditions</u>. Avoid very wet soils which affects machinery mobility and damages the soil. Large tires on harvesting machinery minimizes soil damage when harvesting in wet conditions.
- Size and layout of the plantation: Efficient plantation design with double rows or single rows, and headlands (unplanted areas around the edge of a crop field) to accommodate the efficient turning of machinery and reduce harvester downtime.
- Scale of plantation: Mechanical harvesting of large-scale willow plantation is more efficient.
 <u>Manual harvesting</u> is best suited for small scale willow plantations.
- Quantity of willow plants to be harvested: Land managers should consider the <u>labour and other</u> <u>logistic requirements for the quantity</u> of willow stems to be harvested for efficient harvest operation.

Conclusion

Willow biomass is harvested after three to four years depending on the plant development. Harvesting is done during the dormant season in winter (mid-October to early March) after leaf fall and before bud break in early spring. Harvesting is the single largest cost component of willow biomass production, accounting for about 32 – 60% of costs over the life cycle of the crop (20 plus years). There are multiple ways of harvesting willow including the whole stem harvesters, cut and chip system, and the bundle system. Harvesting can be done in a single step where willow crop is cut directly from the stump and chipped in one operation, or two-step where the willow crop is first cut, stored, and naturally air-dried before later chipping and processing into desired end product. Efforts to reduce harvesting costs by improving the performance and reliability of the harvesters and chip collection system are essential for the profitability of the willow biomass production.

Biomass Connect is funded by the: