Biomass and Bioenergy 108 (2018) 74–89

Contents lists available at ScienceDirect

Biomass and Bioenergy

journal homepage: http://www.elsevier.com/locate/biombioe

Research paper

Predicted harvest time effects on switchgrass moisture content, nutrient concentration, yield, and profitability

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ARTICLE INFO

Article history:
Received 26 January 2017
Received in revised form
11 May 2017
Accepted 23 September 2017
Available online 15 November 2017

JEL:
D24
Q12
Q42

Keywords:
Harvest date
Moisture content
Nutrient removal
Switchgrass
Relative profitability

ABSTRACT

Production costs change with harvest date of switchgrass (*Panicum virgatum* L.) as a result of nutrient recycling and changes in yield of this perennial crop. This study examines the range of cost of production from an early, yield-maximizing harvest date to a late winter harvest date at low moisture and low nutrient concentration using different harvest systems as dictated by the moisture content of the standing crop. Harvest systems with a field-drying interval and multiple harvest passes were compared to a single-pass harvest when moisture content had naturally declined to storage-safe conditions or when artificial drying at the plant would be required. Results showed that the single-pass harvest requiring artificial drying was either i) as costly or more so than declines in yield observed with letting the standing crop dry to 20% moisture in the field; or ii) not economically viable in comparison to multi-pass harvest with a field drying interval at higher yield. Sites where yield losses due to harvest delays were small showed promise for the single-pass harvest at storage-safe moisture, as nutrient replacement costs with greater nutrient recycling and harvest cost savings with a single pass offset yield losses with delayed harvest. Extending the harvest season had different producer cost ramifications amongst environments and led to large changes in nutrient concentrations in harvested biomass. This may be problematic for biorefineries seeking stable nutrient content in feedstock.

1. Introduction

With the current federal target of facilitating the marketing of more than 140 hm^3 of renewable fuels from biomass feedstocks by the year 2022 [1], energy crop producers have the incentive to search for regionally suitable ways to minimize cost of delivered biomass to biorefineries [2]. Switchgrass is a warm-season herbaceous perennial bunchgrass that is native to the prairies of North America [3]. Typical uses for switchgrass include grazing or haying of early-to mid-season growth for livestock as well as late-season harvesting as feedstock for potential conversion to biofuel [4]. It is a relatively drought tolerant, pest and disease resistant, high-yielding cellulosic biomass crop with low input requirements and relatively low cost of establishment [3–6]. Switchgrass also grows on marginal cropland and has the ability to sequester soil organic carbon via its large root system making it a land use choice with small negative repercussions on food supply and environmental footprint [4,6].

Although switchgrass is an advantageous crop for biofuel production [7], the lack of an existing infrastructure for transport and storage of the large volume of low-value bulky material needed at biorefineries to convert to meaningful amounts of liquid fuel

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https://doi.org/10.1016/j.biombioe.2017.09.017

creates a barrier to efficient production [8–10]. Unlike grain ethanol producers, where corn (*Zea Mays* L.) handling facilities exist, small-scale switchgrass producers and biorefineries will face logistical problems associated with storage and transport without a commercially integrated system in place [2,11,12]. Harvest systems can be inefficient with either small scale equipment not designed for handling high volumes of bulky biomass or large scale equipment that is too costly [2] given potential limited annual use by individual farms. As such, a centrally planned system with producer contract growers and large-scale equipment owned and managed by the biorefinery would remove such inefficiencies and allow the inclusion of energy crops by producers on relatively small parcels of land [10]. Further, extending annual field use of equipment with a prolonged harvest season has ownership cost implications as fewer pieces of equipment are needed for annual harvest. Also, since biorefineries need year-round supply, an extended harvest season would lower investment in storage facilities and associated storage losses that add to delivered cost as the crop is stored standing in the field [9–13].

As such, expected biomass yields, stand life, as well as harvest, storage, and transport methods affect the cost of switchgrass when delivered and harvested at different times of the year [10,14]. Driving factors for storage and transportation cost is the moisture content at harvest [5,8–10,13–16]. For example, switchgrass harvest during peak-yielding periods when water content in harvested material at time of cutting exceeds 0.2 kg kg^{-1} requires swathing to allow in-field drying and eventual baling or chopping with a forage harvester. By contrast, delaying harvest to January or February, when the standing crop has naturally dried down sufficiently to preclude swathing, saves equipment, nutrient replacement, and labor cost [17]; however, at the expense of lower recoverable yield in the study region analyzed (Fig. 1). Weathering and leaf loss in the standing crop occur throughout the growing season, but no new growth is added during late fall, which results in harvestable yield loss with late-season harvest [14,16]. Concurrently, crop senescence in the fall initiates i) translocation of nutrients, such as nitrogen (N), phosphorus (P), and potassium (K), to perennating crown and roots; and ii) nutrient recycling from plant material dropping to the ground [18,19]. Both nutrient translocation and recycling add up to fertilizer cost savings with harvest delays [20–23]. Cahill et al. [23] evaluated this harvest time-dependent tradeoff between detrimental yield loss and beneficial nutrient content reductions to determine an optimum harvest date. At the same time, they calculated a profit-maximizing N fertilizer rate as a function of yield response to N, nutrient cost and switchgrass value. This demonstrated economic and biomass nutrient concentration repercussions of harvesting either early or late given a range of input and output prices. Haque et al. [19], in a similar economic analysis, revealed that land with soils deficient in K are more responsive to changes in prices received for biomass than the cost of fertilizer. Hence, both crop price and input costs play an important role for determining cost-minimizing harvest strategies.

Finally, given the need for eventual particle size reduction for processing, a single-pass harvest involving direct chopping of standing biomass that has naturally dried down late in the harvest season with a forage harvester equipped with a mower header reduces total processing energy requirements along the production chain [13] as a separate mowing pass to allow for in-field drying before eventual chopping is avoided. The single-pass harvest, however, requires a more expensive mower header than a pick-up header for the forage harvester. Therefore, storing biomass in-field may offer an economically viable alternative to hay-type harvest and storage methods although snow and rainfall may impede harvest progress.

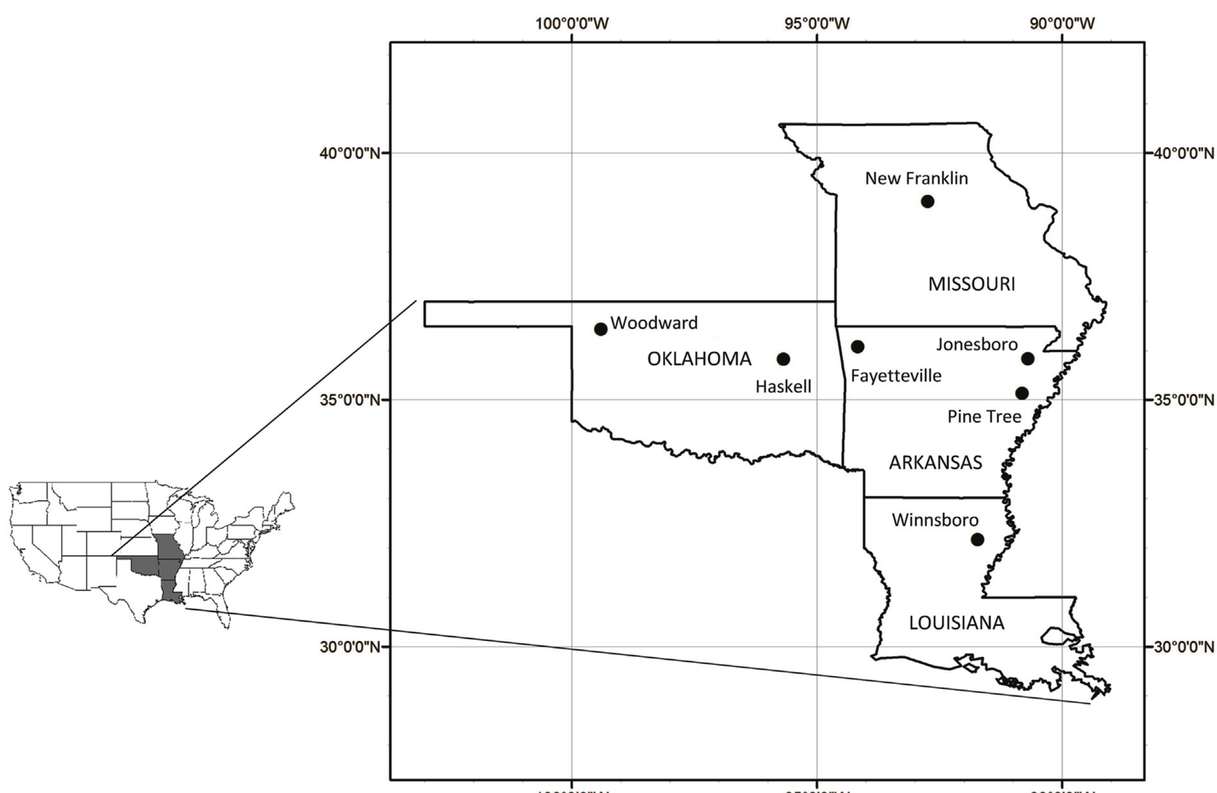

Fig. 1. Map of study locations.