Millions of Acres for Dedicated Energy Crops: Farms, Ranches, or Plantations?

Francis M. Epplin
Oklahoma State University

TRANSITION TO A BIO ECONOMY

Integration of Agricultural and Energy Systems

February 12-13, 2008

Atlanta, GA

OKLAHOMA STATE UNIVERSITY

Cellulosic Ethanol

- Energy Independence and Security Act of 2007
  - By 2022, 21 billion gallons of ethanol to be derived from non-cornstarch products (e.g. sugar or cellulose)

Feedstock for Cellulosic Ethanol

Billion Ton Biomass Study (DOE; USDA 2005)

- One billion dry tons from agricultural lands
  - sustainably collectable biomass and continue to meet food, feed and export demands (p. 38)

Land for Dedicated Energy Crops

- DOE; USDA 2005
  - 55 million acres of cropland, idle cropland, and cropland pasture

- English et al. 2006
  - Switchgrass could be established on more than 100 million acres

Feedstock Acres

- 21 billion gallons (2007 Energy Act)
- 90 gallons per ton (DOE NREL goal)
- 3 - 7 dry tons per acre
- 33 - 78 million acres
- In 2007 US farmers planted
  - 60 million acres of wheat
  - 64 million acres of soybeans
  - 94 million acres of corn

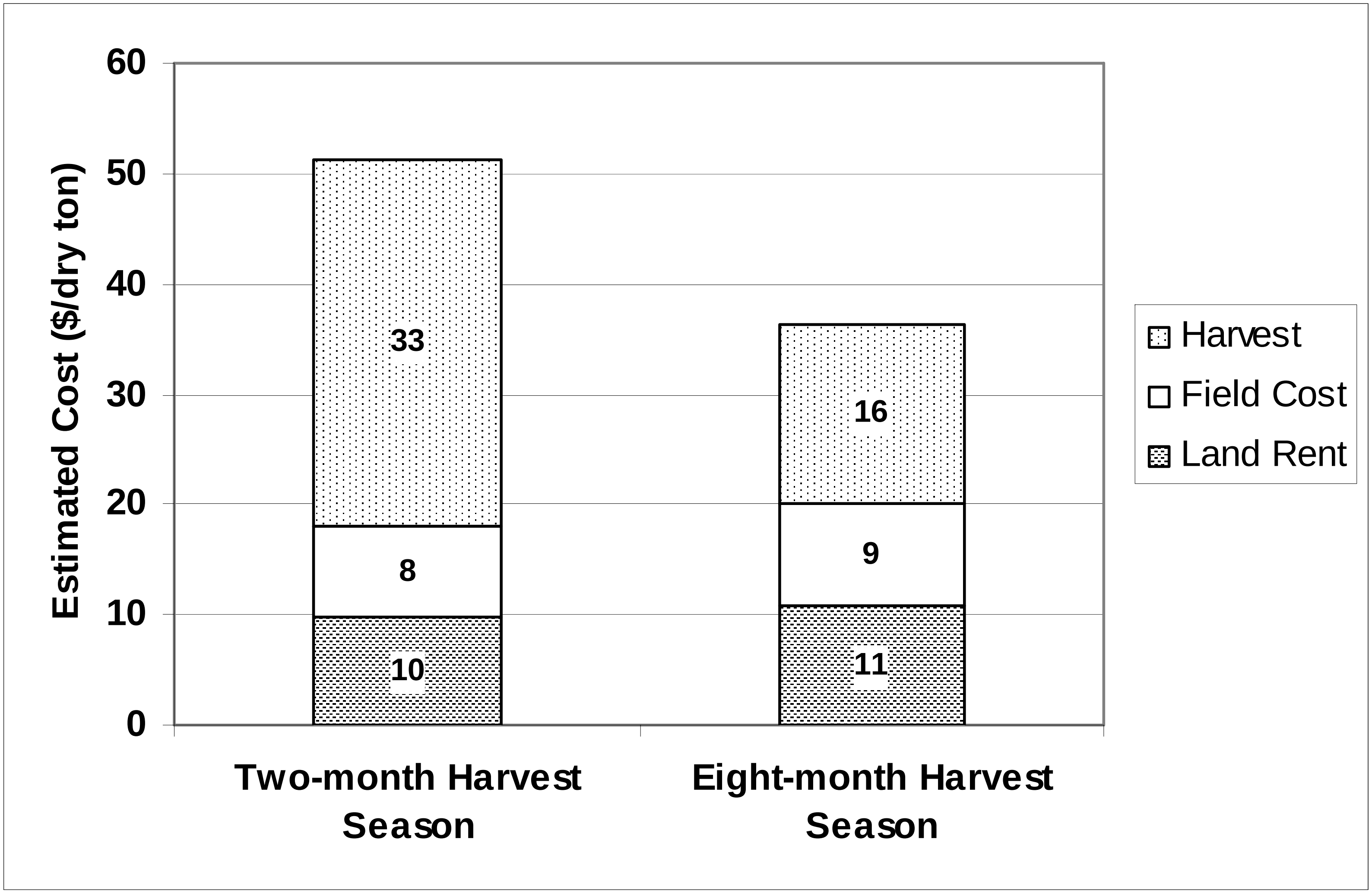

©2001, Okla. St. Univ.

Feedstock Production, Harvest, Storage, Transportation Challenges

- Unlike corn grain, harvest, storage, transportation, marketing, and risk management infrastructure does not exist
  - Spot markets work fine for corn grain
  - Spot markets don’t exist for switchgrass
- Continuous year-round flow of material to biorefinery
- Substantial investment required in harvest machines
- Large quantity of bulky material

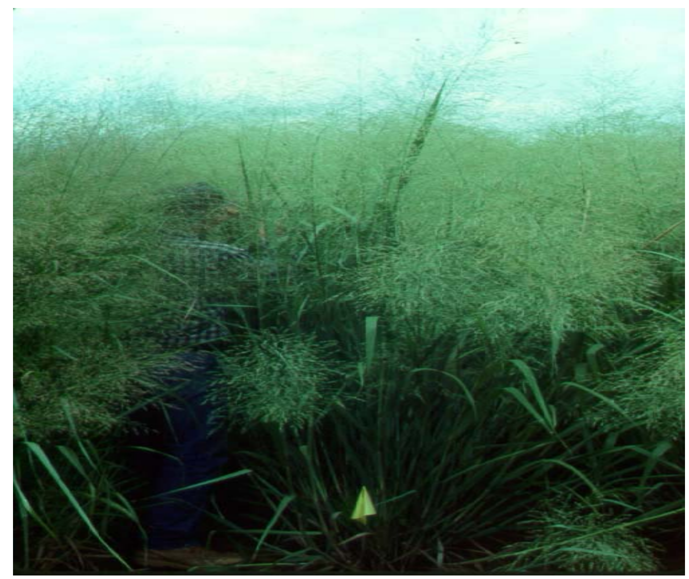
Harvest Costs

(45-65 % of “Farm Gate” Production Costs)



What Industry Structure

- Perennial grass
- After establishment year, very little annual maintenance required
  - One trip to broadcast fertilizer
  - Harvest
- Cost components:
  - Land
  - Establishment
  - Fertilizer
  - Harvest



- Structure likely to be determined by the most efficient harvest, storage and transportation system

Objective

- Determine the most efficient harvest system for a dedicated energy perennial grass such as switchgrass
  - 21 billion gallons (2007 Energy Act)
  - 3 - 7 dry tons per acre
  - 33 - 78 million acres

What Harvest System

- It depends on whether the processing system prefers
  - dry versus wet
  - loose versus dense

- It depends upon which cellulose processing technology “wins”
  - enzymatic hydrolysis
  - acid hydrolysis
  - gasification
  - gasification-fermentation
  - liquefaction
  - mixalco

Assumption For Discussion Purposes

- Biorefinery uses the

  Oklahoma State University-

  University of Oklahoma-

  Coskata

Gasification Bio-fermentation Process

Gasification Bio-fermentation

- Gasification - feedstock converted to synthesis gas
  - “dry” feedstock is preferred

- Bio-fermentation - synthesis gas converted into ethanol and other products
  - “…more than 100 gal / dry ton…”

- DOE, NREL enzymatic fermentation
  - goal of 90 gal / dry ton

» http://www.coskataenergy.com/process.html

Gasification Bio-fermentation

- Gasify dry feedstocks
- Gasification could use a variety of feedstocks
  - Switchgrass; miscanthus; corn stover; bagasse

(Note: technology remains unproven)

Quantity of Feedstock Required for a 4,000 tons per day Biorefinery

- 1,400,000 tons of biomass per year
- 350 days of operation per year
- 17 dry tons per truck
- 235 trucks per day
- 24 hours per day
- 9.8 trucks per hour

Quantity of Feedstock Required for a 4,000 tons per day Biorefinery

- 1,400,000 tons / y / biorefinery
- 470,000 (3 t/a) to 200,000 (7 t/a) acres
- 126 million gal / y / biorefinery (90 gal/t)
- 167 biorefineries to produce 21 billion gal / y (33 - 78 million acres)

Which Harvest Method?

- Current forage harvest systems
  - Small bales
  - Large cylindrical solid bales
  - Large rectangular solid bales
  - Loose chop
  - Cotton module systems
  - Silage systems

- Collect for field storage and transport substantial distances

- For large volume, and current forage harvest technologies, large rectangular solid bales is the least-cost system for harvesting biomass from perennial grasses in the Western Plains

Bale

Collect
Bales
and
Stack for
Field
Storage

How Would Harvest be Managed ?

- Harvest Costs
  45-65 % of “Farm Gate” Production Costs

Experience from Custom Grain Harvest Companies (Great Plains)

- A substantial quantity of the grain in the Great Plains is Harvested by Custom Harvest Companies

	Average
• Acres Harvested per Year	28,049
• Number of Combines	4.1
• Number of Trucks	6.3
• Number of Employees	10.3

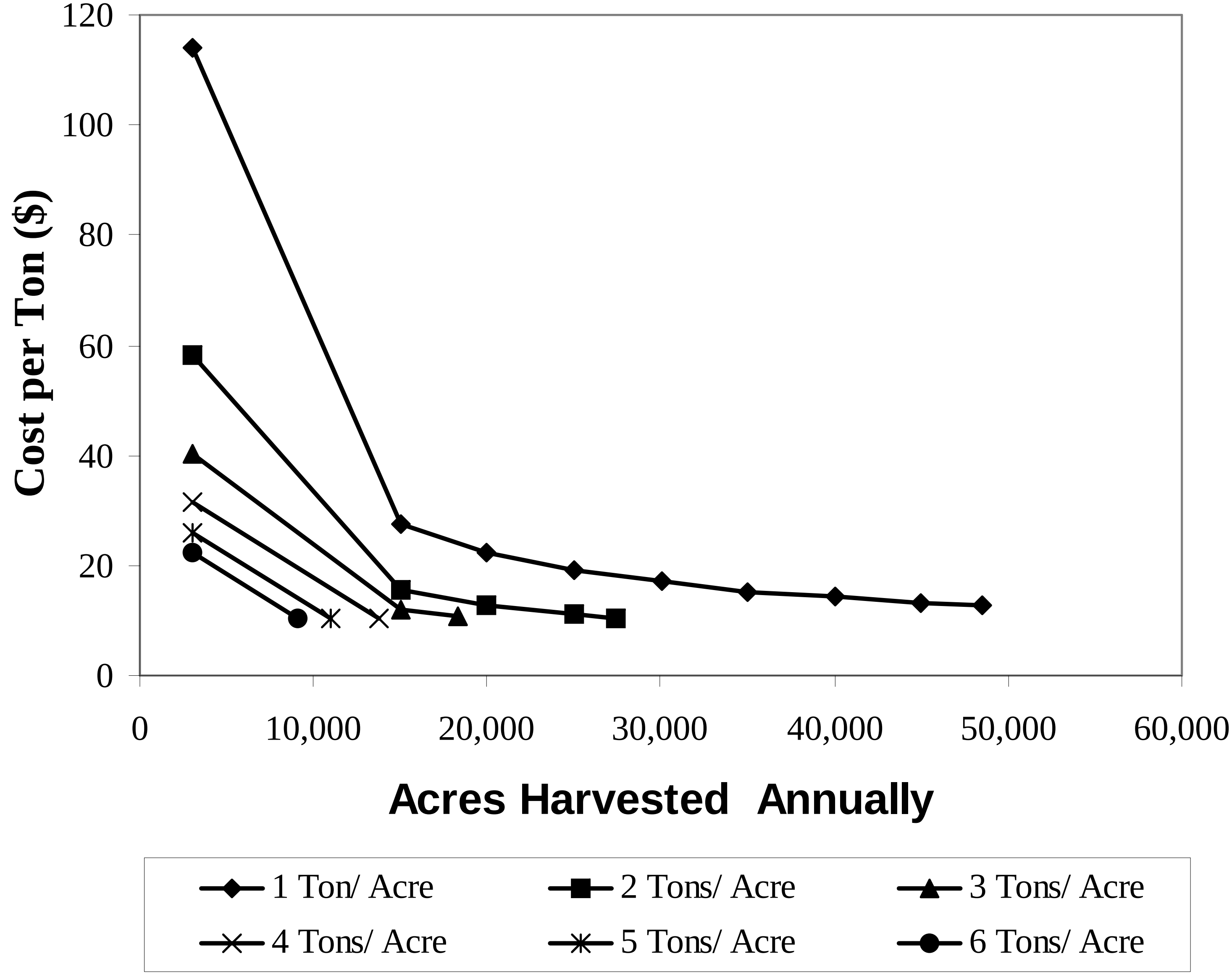
(Source: Kastens and Dhuyvetter, 2006)

Conceptual Coordinated Harvest System for Switchgrass

- Mowers
- Rakes
- Balers
- Tractors
- Field Stacker
- Workers

(Source: Thorsell et al.)

Harvest and Stacking Cost
Economies of Size



Model

- Multi-region, multi-period, mixed integer mathematical progamming model
  - Tembo et al. 2003. *JARE* 28:611-633.
  - Mapemba et al. 2007. *RAE* 29:227-246.

- Cropland
  - Conversion to Switchgrass

Economic Modeling

- determine the cost to

  produce,

  harvest,

  store, and

  transport

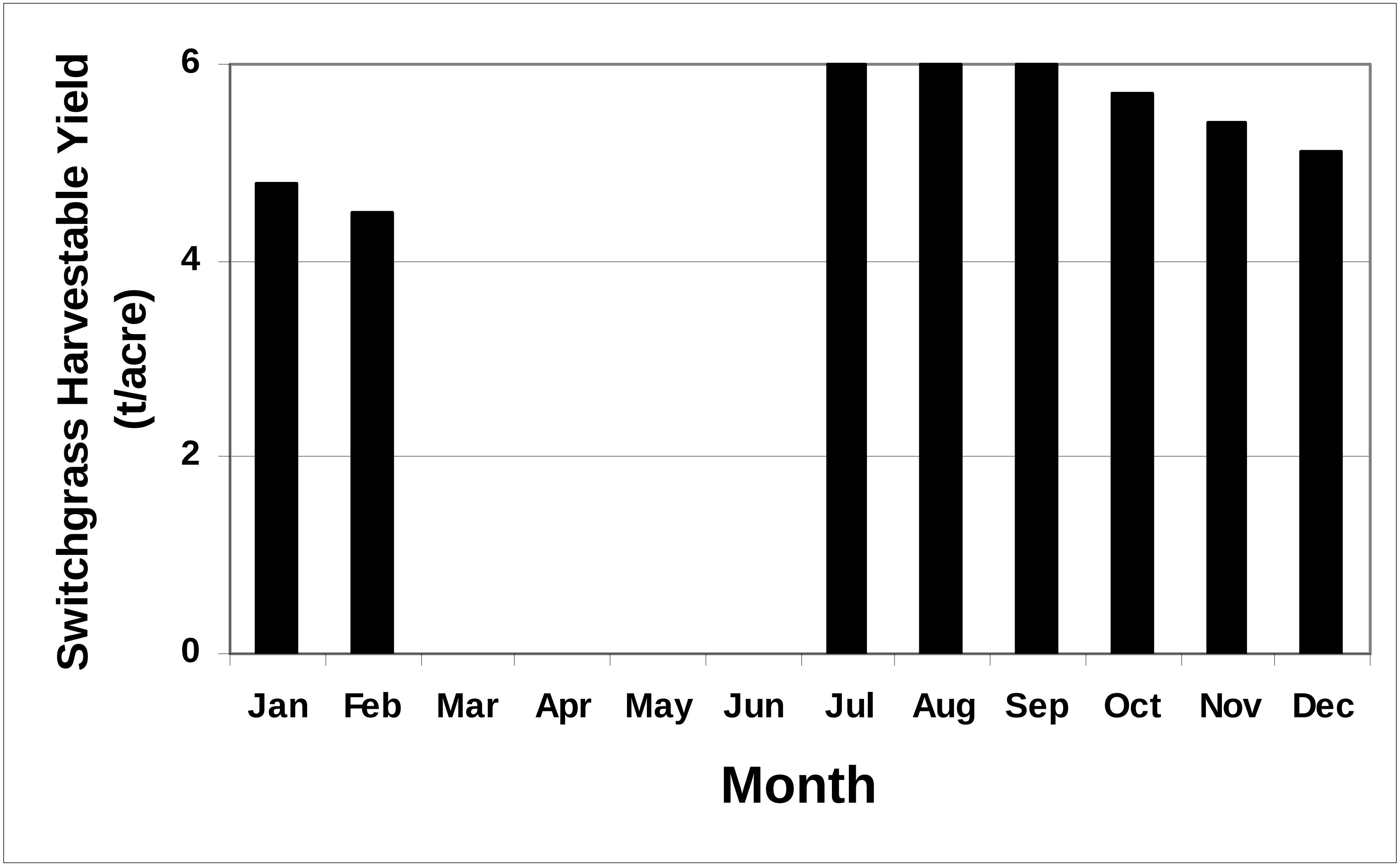
  a flow of biomass from perennial grasses produced in the Great Plains to an optimally located and sized biorefinery

Number of Harvest Machines Endogenously Determined

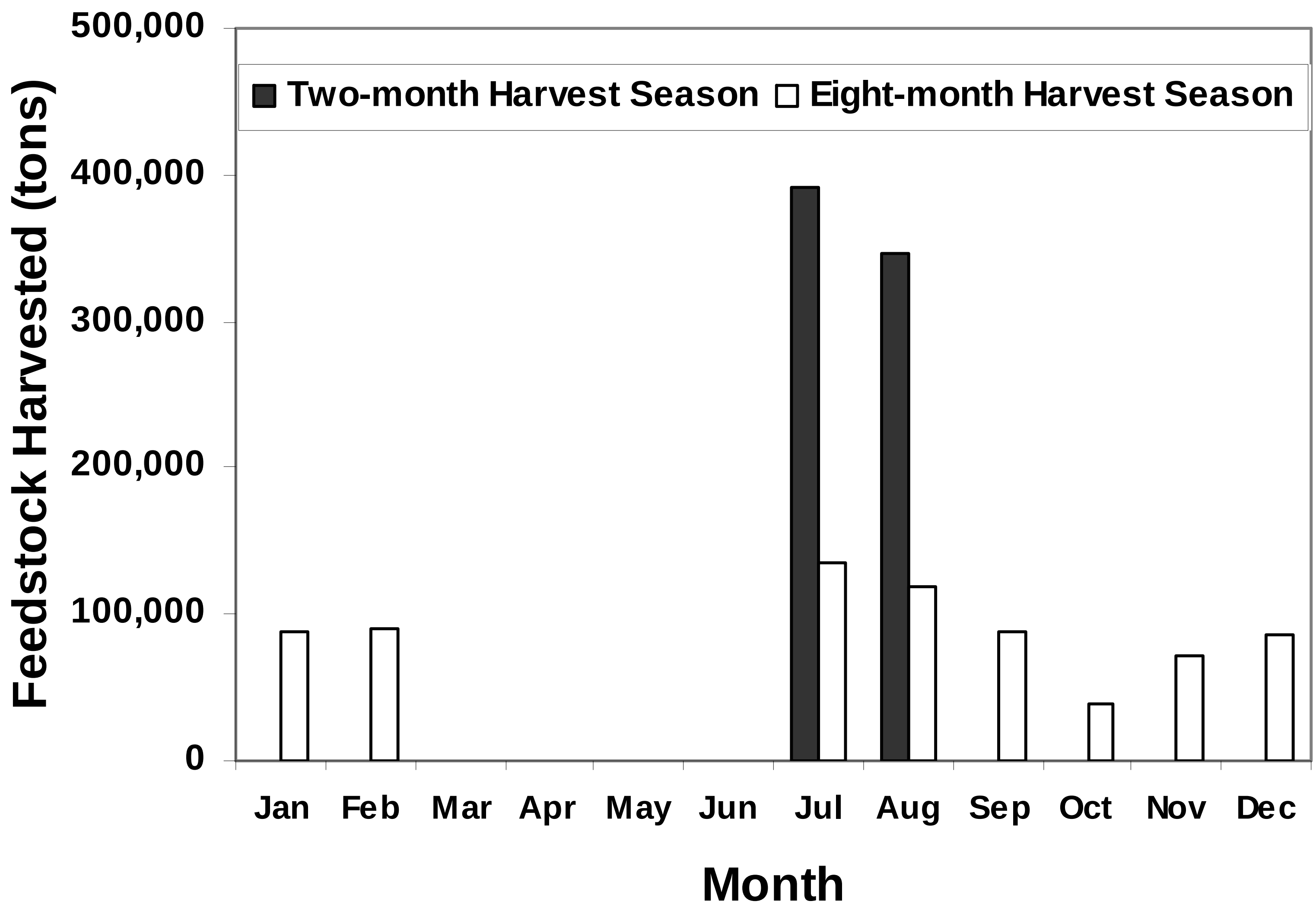
- Large rectangular solid bales
- Field workday distributions built from historical weather data (Mesonet system)
  - Mowing days
  - Raking, baling, stacking days
- Single harvest per year
  - 8 month harvest window (Jul – Feb)
- 2,000 dry tons per day

Swithgrass Expected Harvestable Yield (tons/acre)

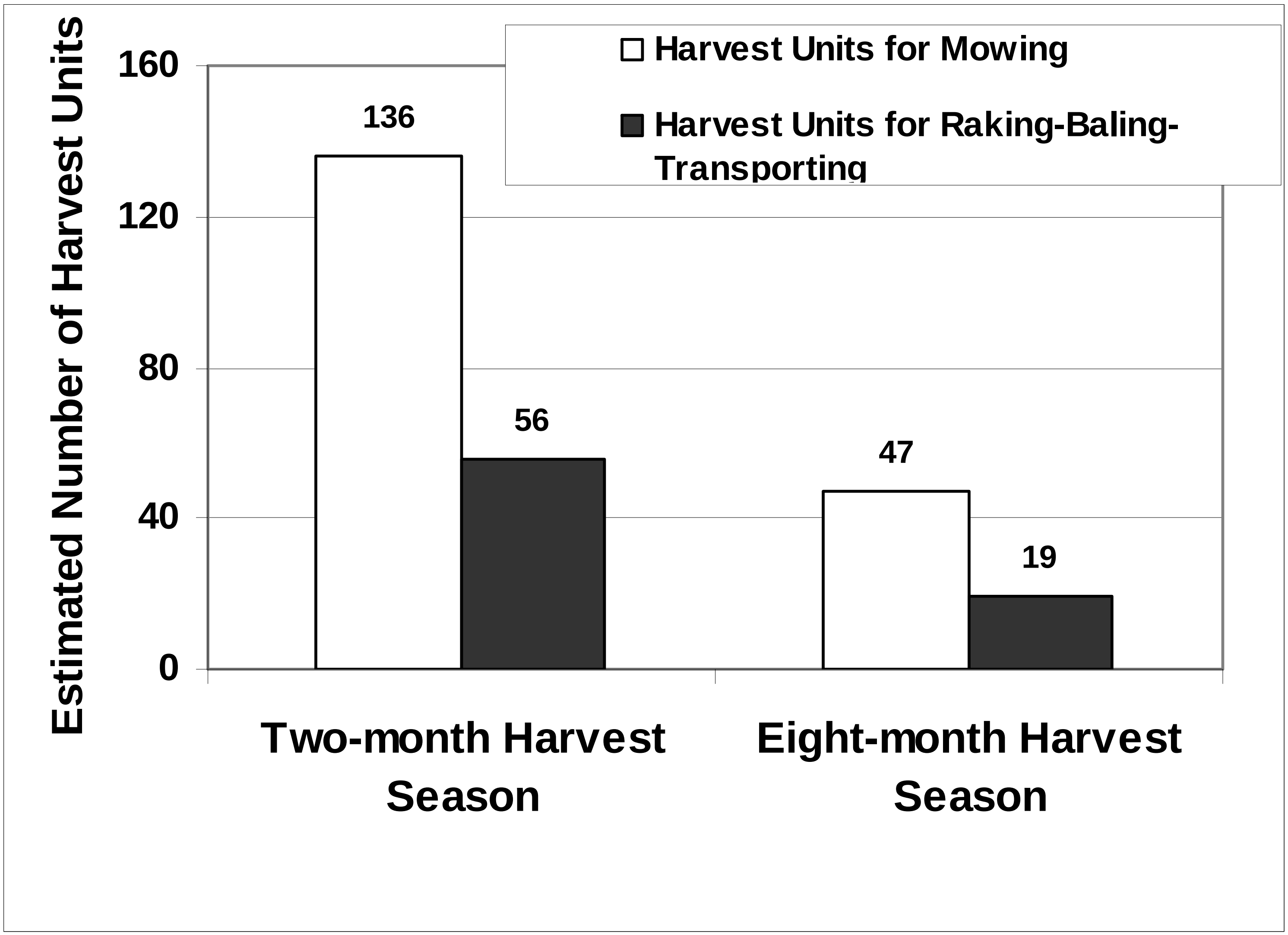
expected yield 6.5 to 3.75 t/a depending on county and month of harvest



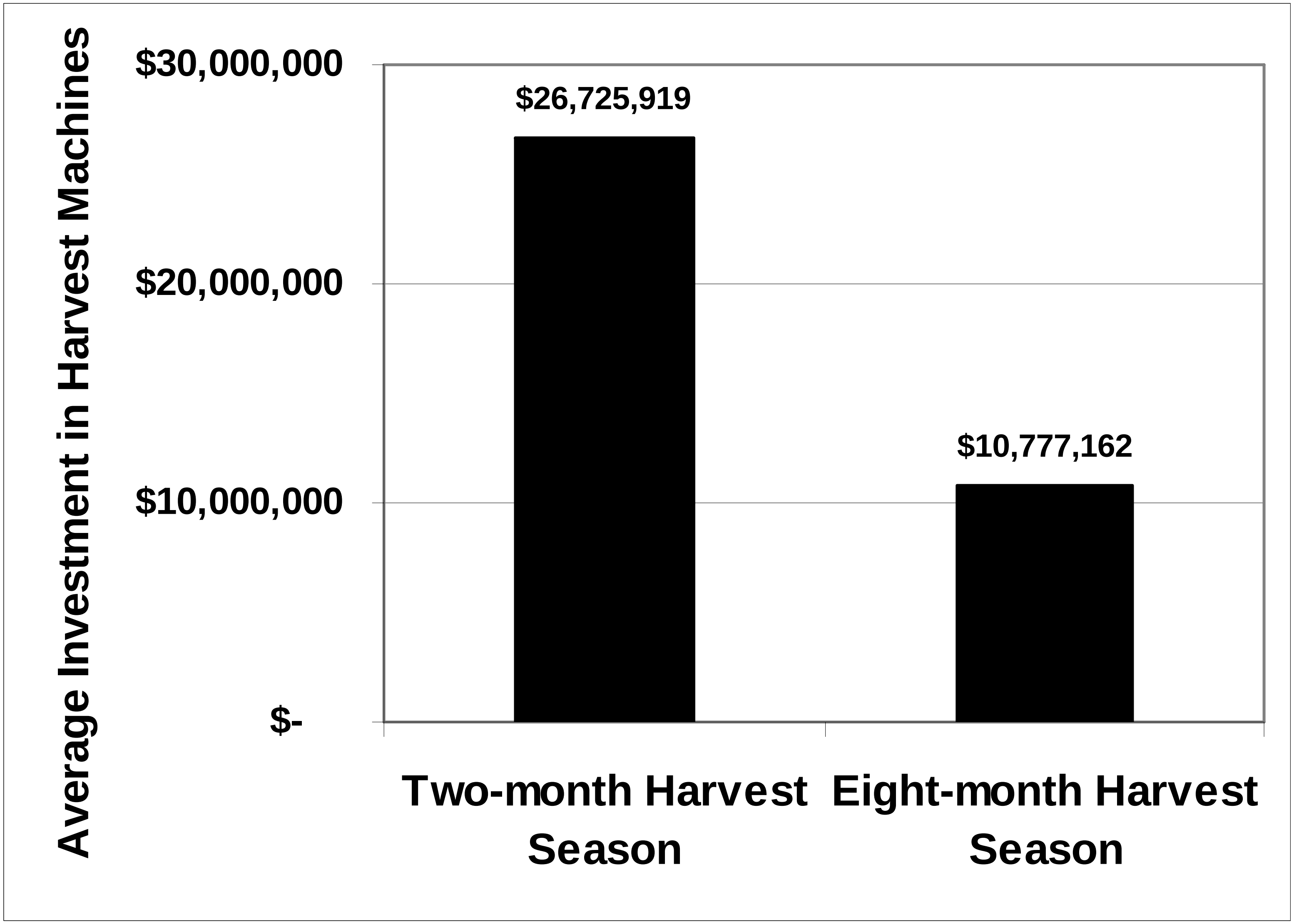
Switchgrass harvested per month for both a two- and eight-month harvest season to provide a flow of feedstock to a 2,000 dry tons per day biorefinery



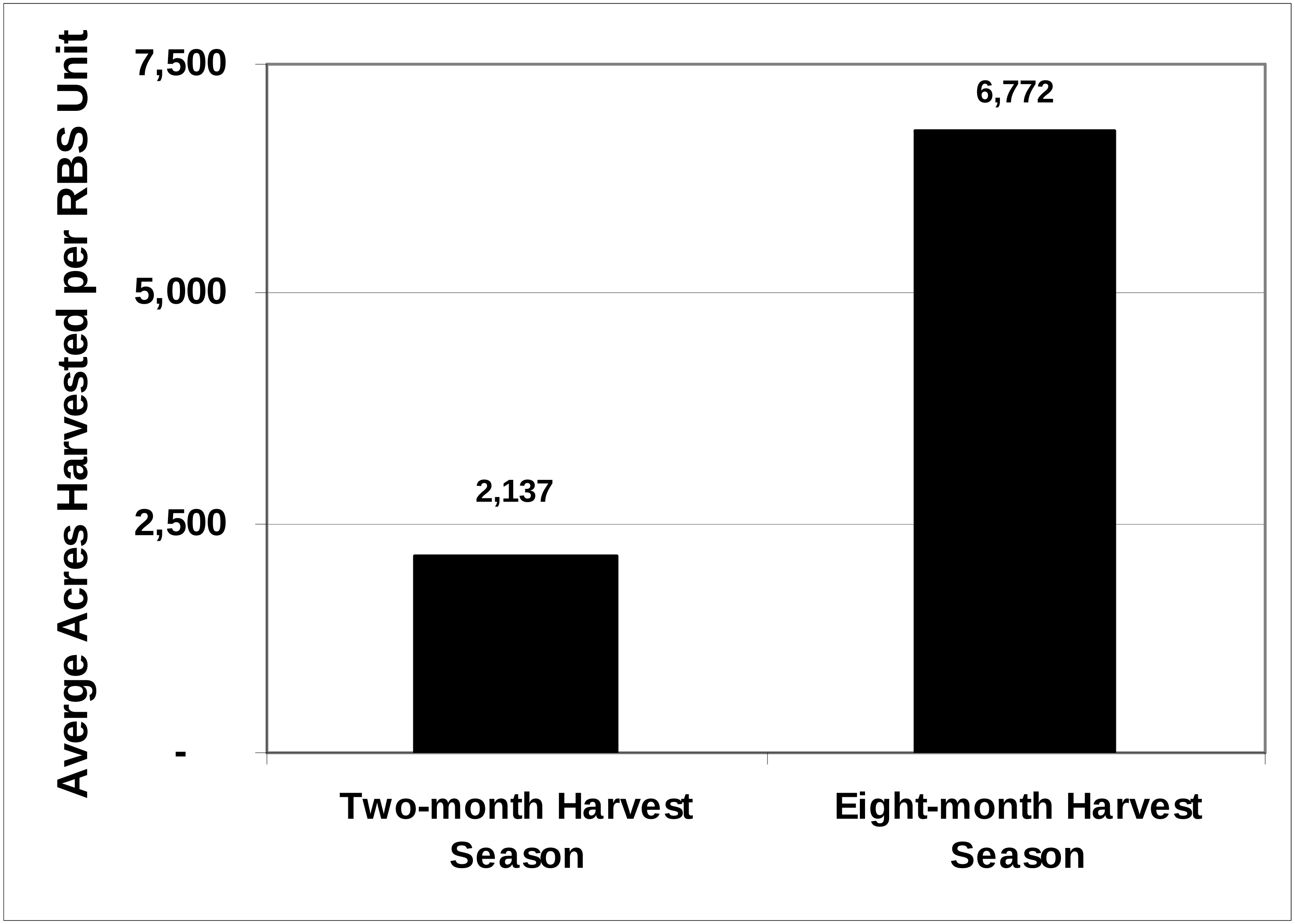
Estimated number of harvest machines for two- and eight-month harvest season to provide a flow of 2,000 t/day



Average investment in harvest machines for two- and eight-month harvest season to provide a flow of 2,000 t/day

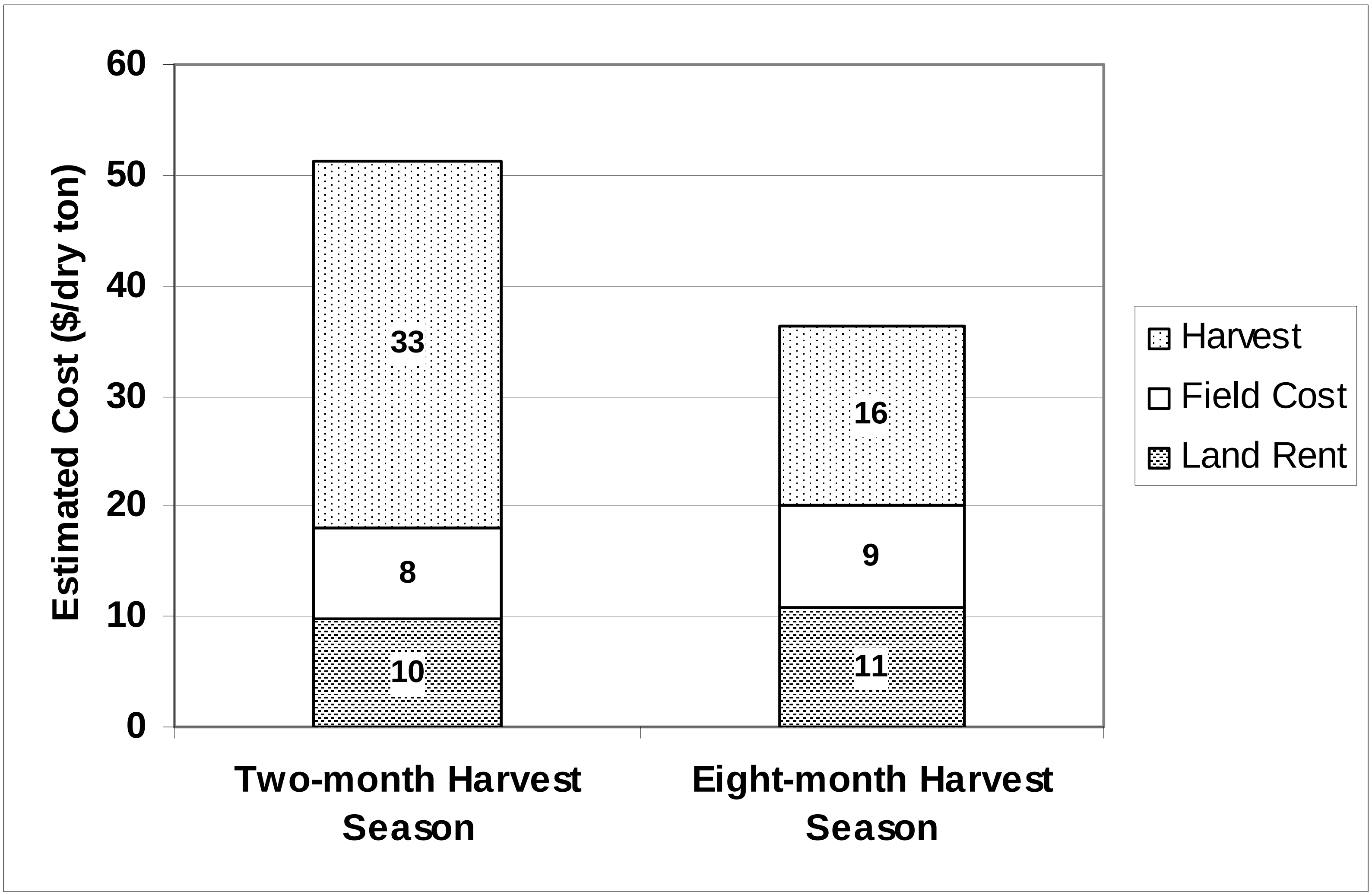


Estimated number of acres harvested per year per raking, baling, stacking harvest unit for two- and eight-month harvest season to provide a flow of 2,000 t/day



“Farm Gate” Costs

(45-65 % for Harvest)



What do the Models Tell Us?

- Significant cost economies associated with harvest machines
- Harvest would extend over as many months as permitted by weather, feedstock sources, and policy
- Market forces would exploit the economies of size associated with harvest machines
  - independent harvest companies
  - wholly owned subsidiaries of biorefineries

Industry Structure

- Production characteristics and harvest cost economies more similar to U.S. timber production than to U.S. grain, oilseed, and fiber production

- Market forces may drive the structure toward vertical integration

- Feedstock production, harvest, and transportation may be centrally managed and coordinated

- Public policy that restricts business ties between feedstock production and feedstock processing is likely to hinder the development of a cellulosic biomass biorefinery industry

Quantity of Feedstock Required for a 4,000 tons per day Biorefinery

- 1,400,000 tons / y / biorefinery
- 470,000 (3 t/a) to 200,000 (7 t/a) acres

Possible Arrangements to Insure a Reliable Flow of Feedstock

- Acquire Land
- Long-term land leases similar to Conservation Reserve Program
- Contract with individual growers
- Contract with a group of growers via cooperative arrangement

Additional Challenges

- Risk management
  - Feedstock yield variability
  - Fire of standing and stored switchgrass

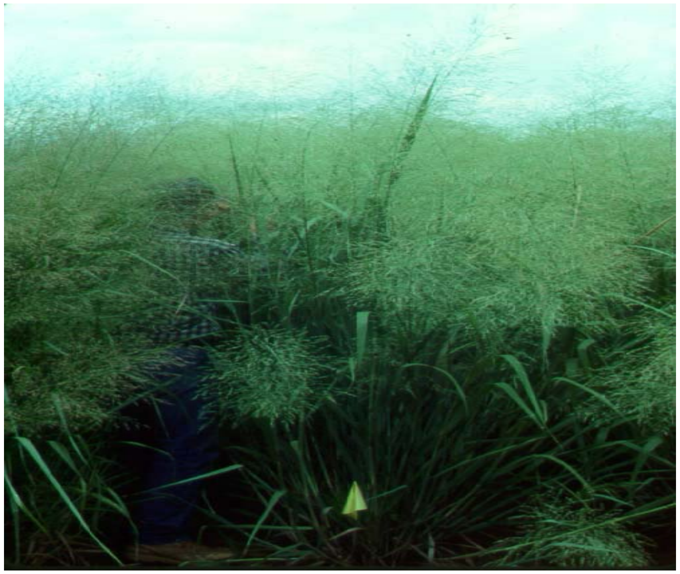
- 55 million acres of cropland, idle cropland, and cropland pasture identified in the billion ton study are widely dispersed

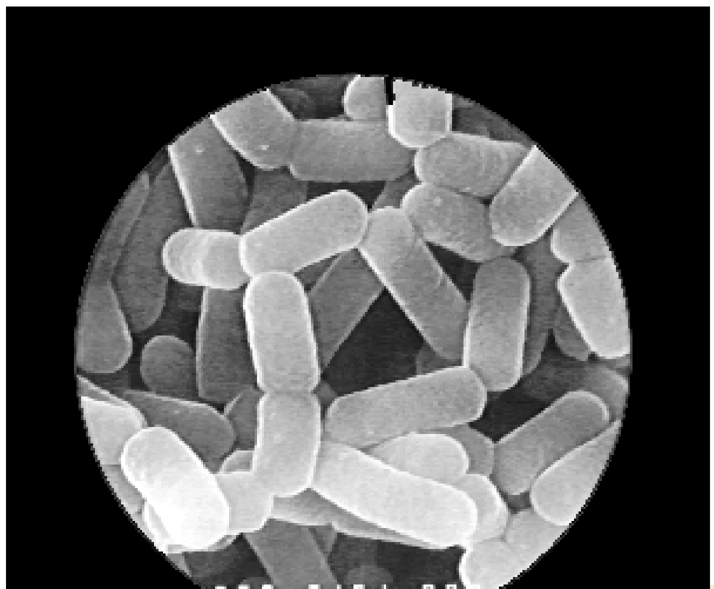
- The grain-ethanol program has increased the cost of inputs (land, fertilizer, machinery) required to produce switchgrass

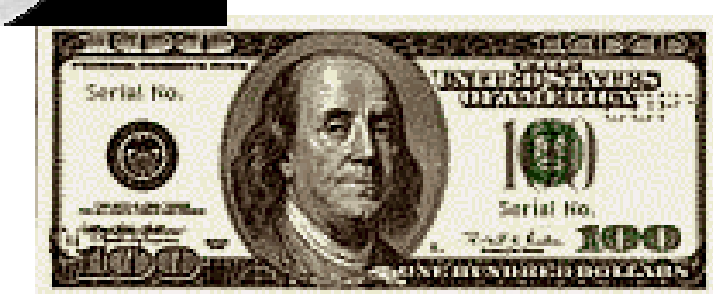
- Discover, develop, design, and demonstrate an economically competitive biorefinery technology

- Build a **profitable business model**

OKLAHOMA STATE UNIVERSITY AGRICULTURE






Serial No.
UNITED STATES OF AMERICA
100
Serial No.
100
ONE HUNDRED DOLLARS