Development of a Single-Pass Cut-and-Chip Harvest System for Short Rotation Woody Crops

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Outline

- Funding support and project partners
- Project objective
- Background on single pass cut and chip system
- Harvester effective material capacity (throughput)
- Harvesting system efficiency
- Harvesting cost improvements
- Commercialization of systems

Funding Support

US Department of Energy – Biomass Program

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

BIOMASS PROGRAM

New York State Energy Research and Development Authority

nyserda

Energy. Innovation. Solutions.

NYSTAR - Technology Transfer Incentive Program

NYSTAR®

Empire State Development
Division of Science, Technology & Innovation

USDA

United States Department of Agriculture

National Institute of Food and Agriculture

Project Partners

Manufacturers - Growers - Consumers

ESF
State University of New York
College of Environmental Science and Forestry

NEW HOLLAND
AGRICULTURE

GREENWOOD
RESOURCES
A Resource That Lasts Forever™

ZeaChem

Applied
Biorefinery
Sciences

Mesa
Reduction Engineering & Processing, Inc.

Objective

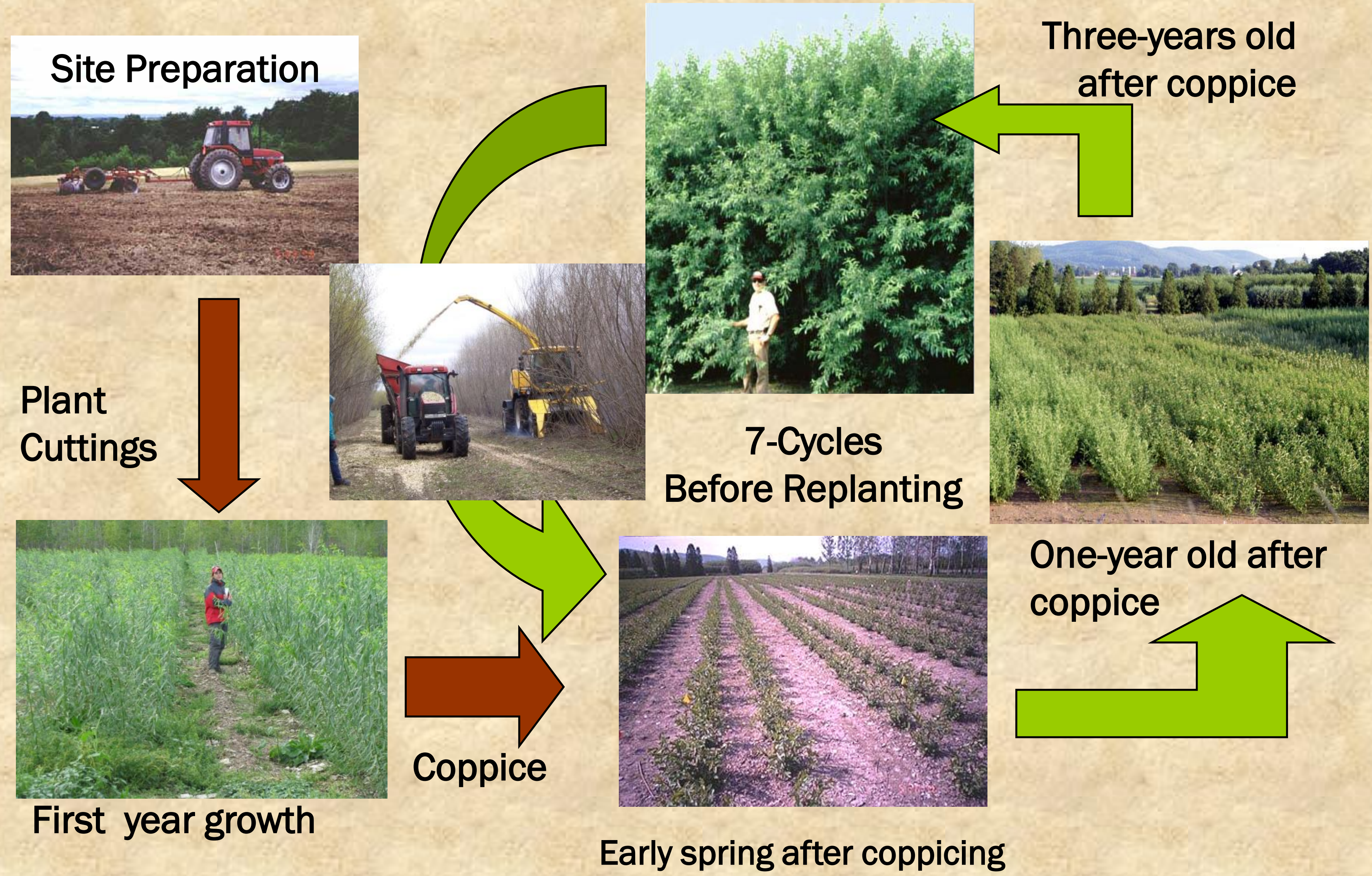
Evaluate Performance

- Multi-Crop (e.g. corn silage, haylage, woody crops) harvester in a single-pass, cut and chip harvesting system in short rotation woody crops
  - New Holland FR-9000 series forage harvester
  - FB-130 short rotation coppice header

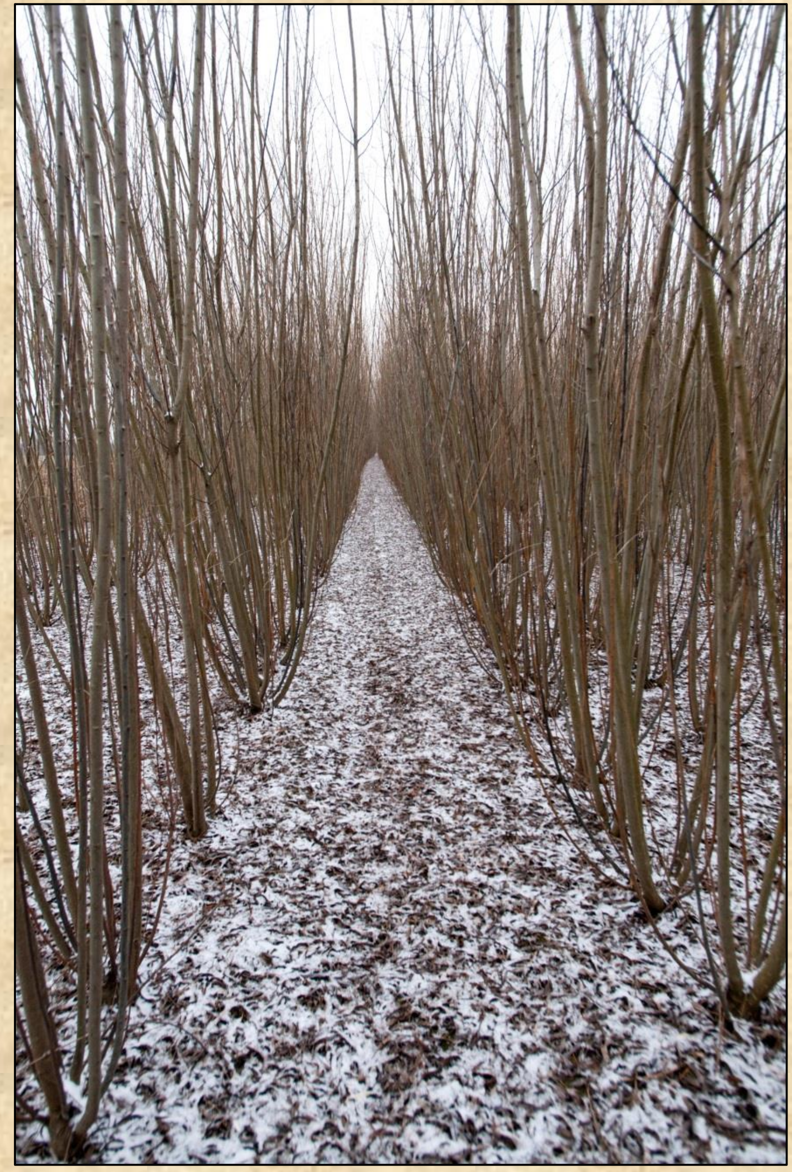
Short Rotation Woody Crops
Focus on the Harvesting System

- Single largest cost for delivered chips from short rotation woody crops
- 30 to 50% delivered cost in willow biomass crops (Buchholz and Volk, 2011)
- Second largest source of GHG emissions after N fertilizer (Heller *et al* 2003)

Willow Biomass Production Cycle



Three Year Old Willow Biomass Crops

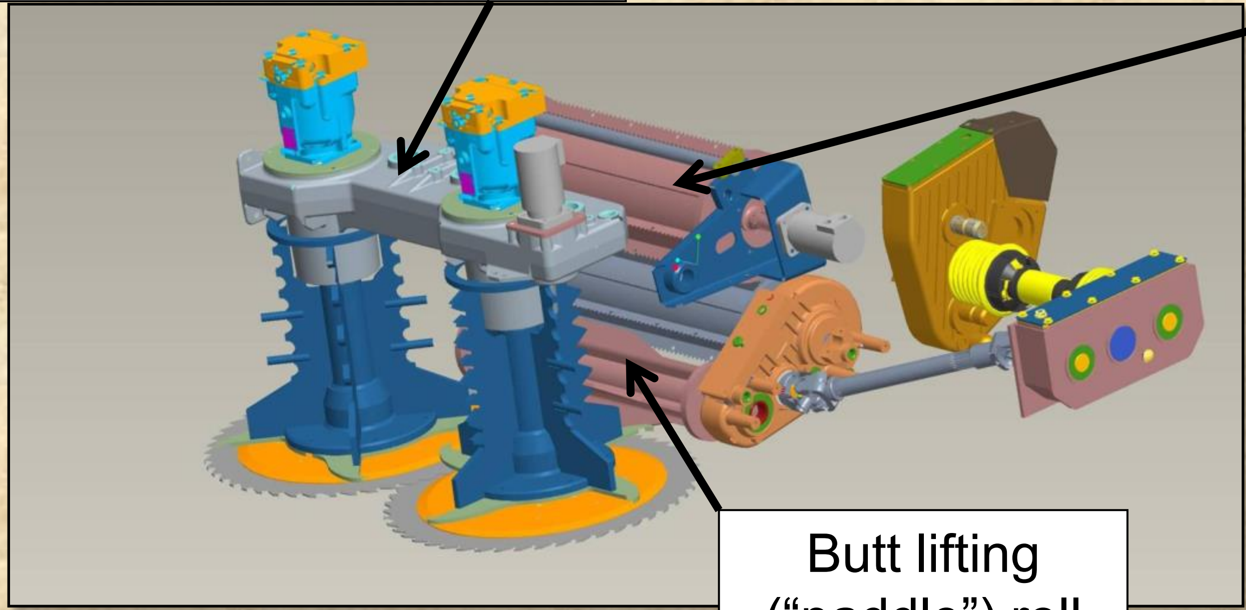


Woody Crop Harvester Concept

Develop woody crop cutting head that snaps onto standard forage harvester with no changes to forage harvester

Modified sugar cane harvester cutter gearbox

Extra feed rolls in header to assist crop feeding

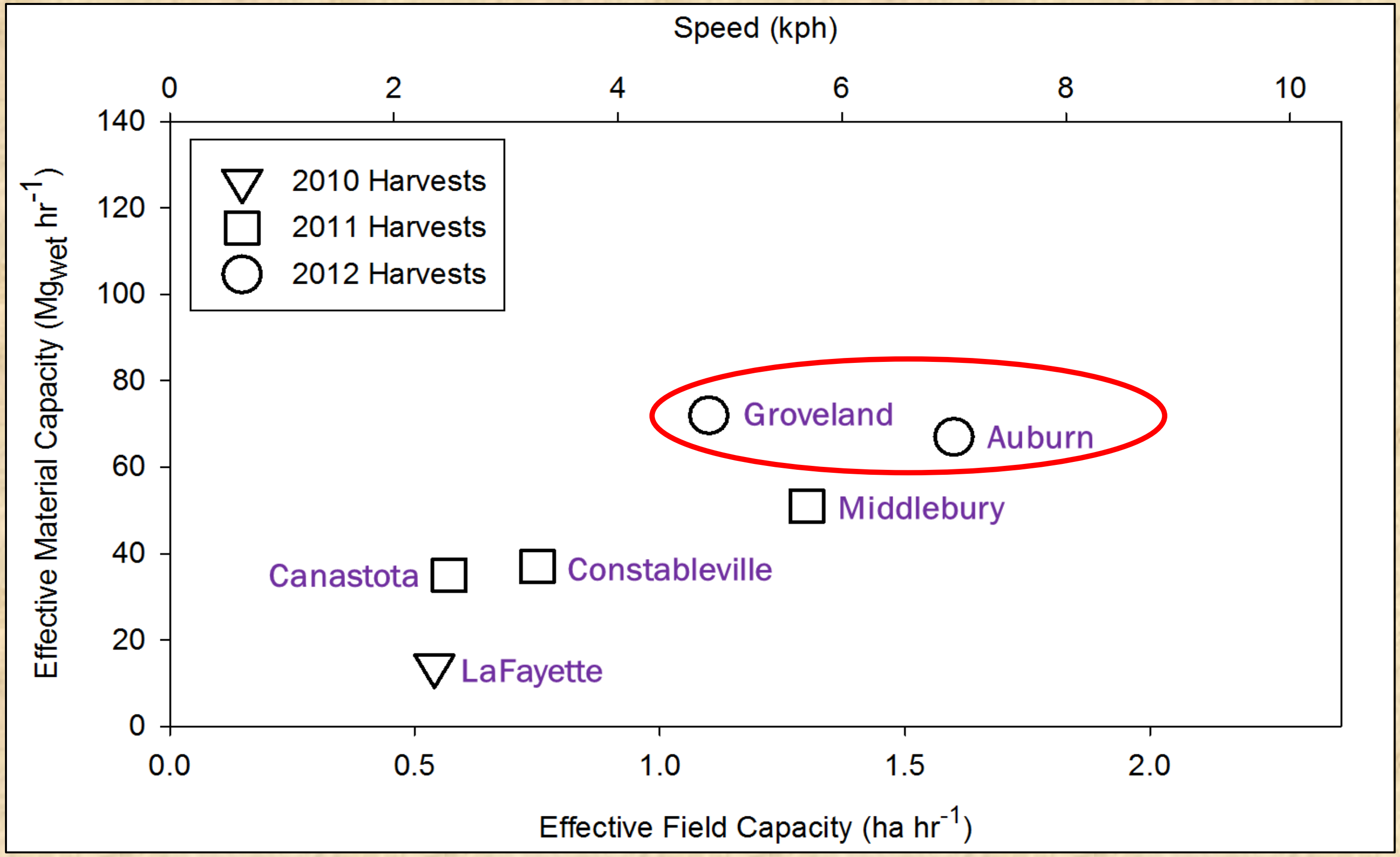


Butt lifting (“paddle”) roll

Iterative Testing Process

Harvesting Willow Biomass Crops

Harvester Improvements Over Three Years



Improvements in effective material capacity for several willow harvests from below 20 Mg_{wet} hr^{-1} to about 70 Mg_{wet} hr^{-1} as observed over the three-year project.

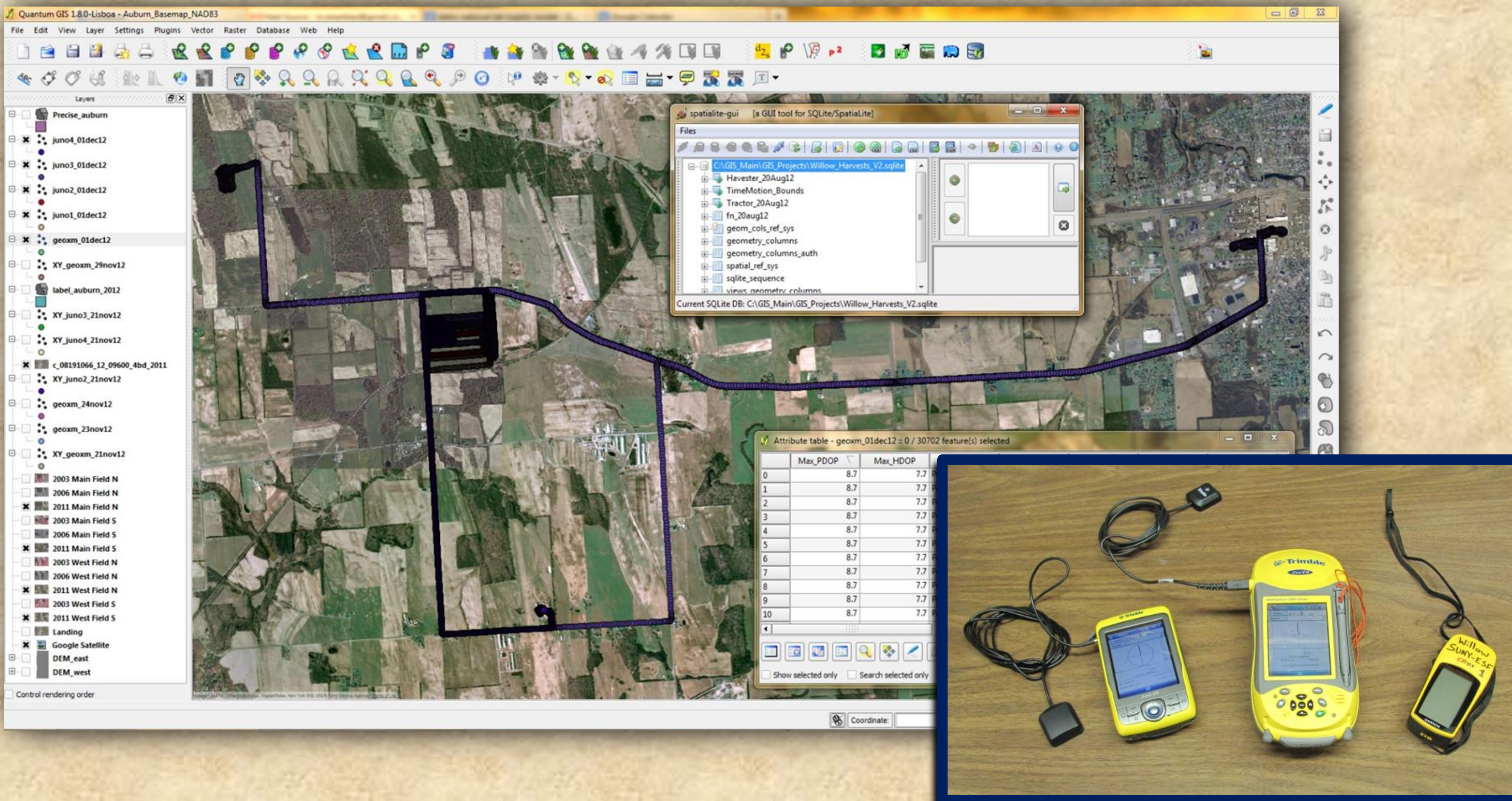
Operational Characteristics

Auburn and Groveland Harvests

- Commercial-scaled (40 – 50 ha)
  - But had spacing and headland issues
- Experienced operator
- Locally-sourced collection system
- Optimize throughput
  - Material capacity $Mg_{wet}\ hr^{-1}$
- Harvester engine loading at or near 100%

Time Motion Methods

❖ 1 harvester and 2-4 collection vehicles operating per day; over 1,000,000 GPS data points collected



Harvester Performance

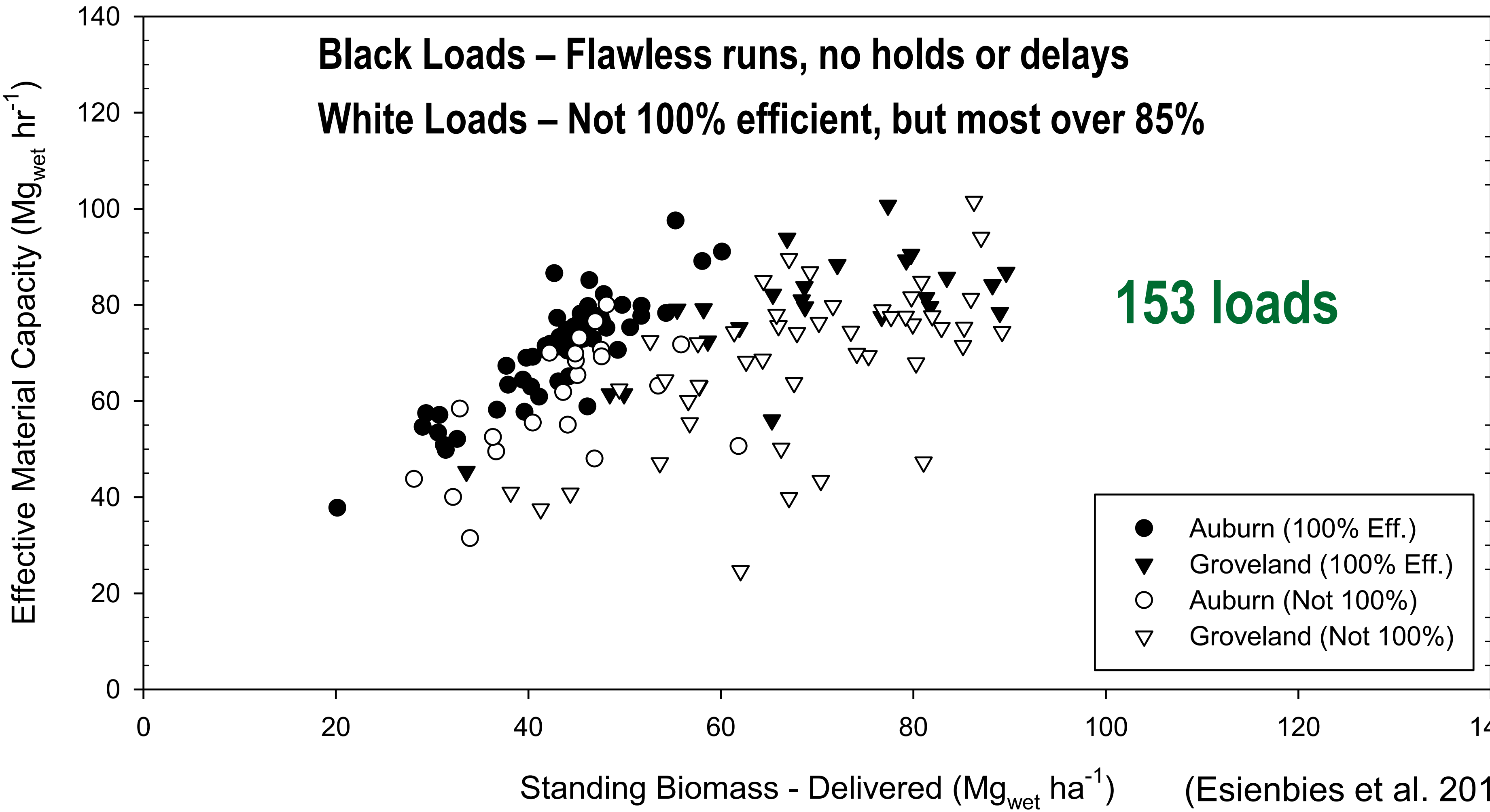
Site	Effective Field Capacity ($ha\ hr^{-1}$) SPEED	Effective Material Capacity ($Mg_{wet}\ hr^{-1}$) THROUGH PUT	Standing Biomass Delivered ($Mg_{wet}\ ha^{-1}$)
Auburn	1.6 ± 0.02	67 ± 1.4	43 ± 0.8
Groveland	1.1 ± 0.2	72 ± 1.9	68 ± 1.6

(Esienbies et al. 2014)

Harvester In Field Performance

Throughput-EMC (Mg_{wet} hr^{-1}) vs Std Biomass (Mg_{wet} ha^{-1})

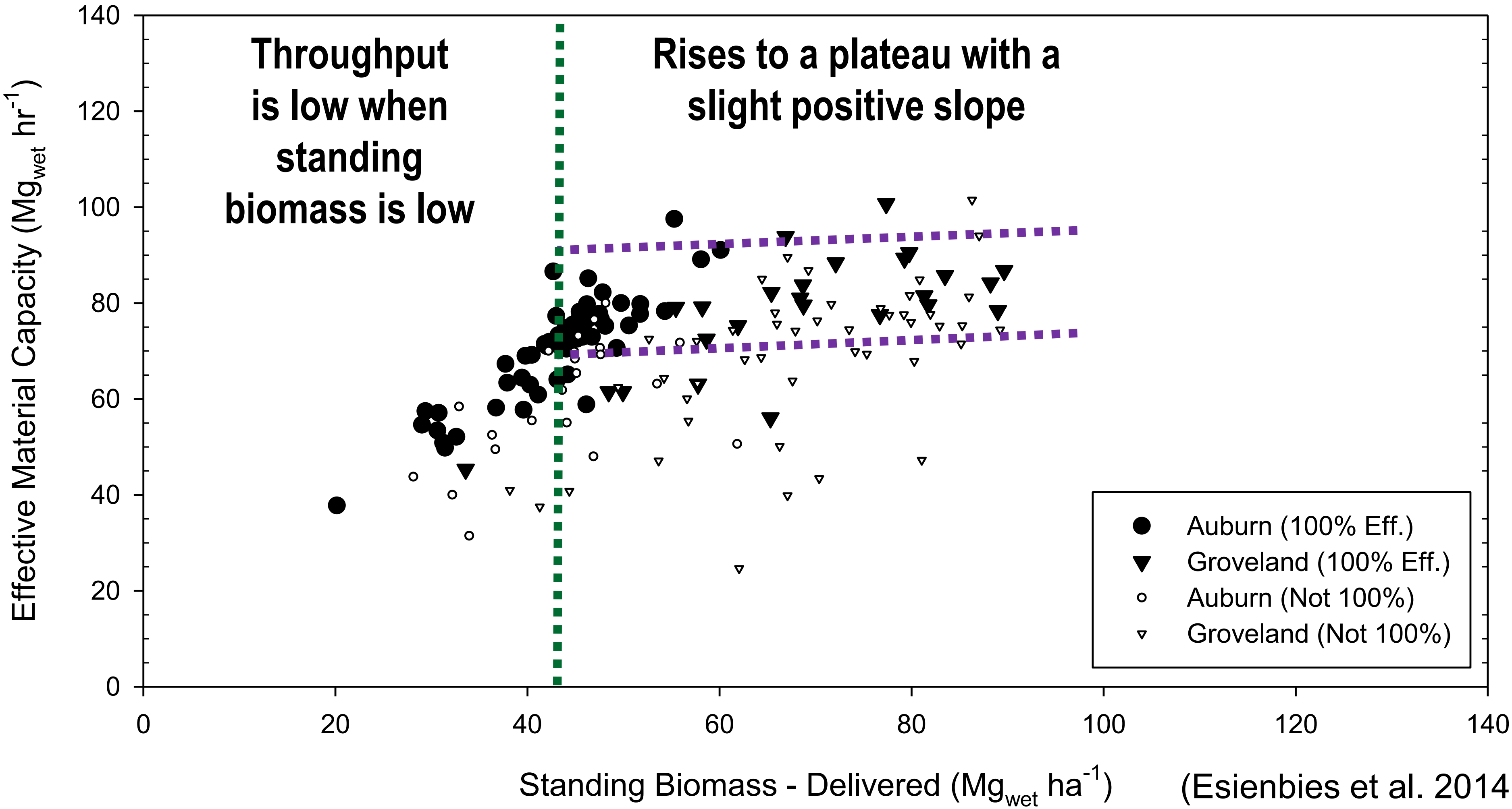
(FR-9060 running at > 85% efficiency in these conditions)



(Esienbies et al. 2014)

Harvester In Field Performance

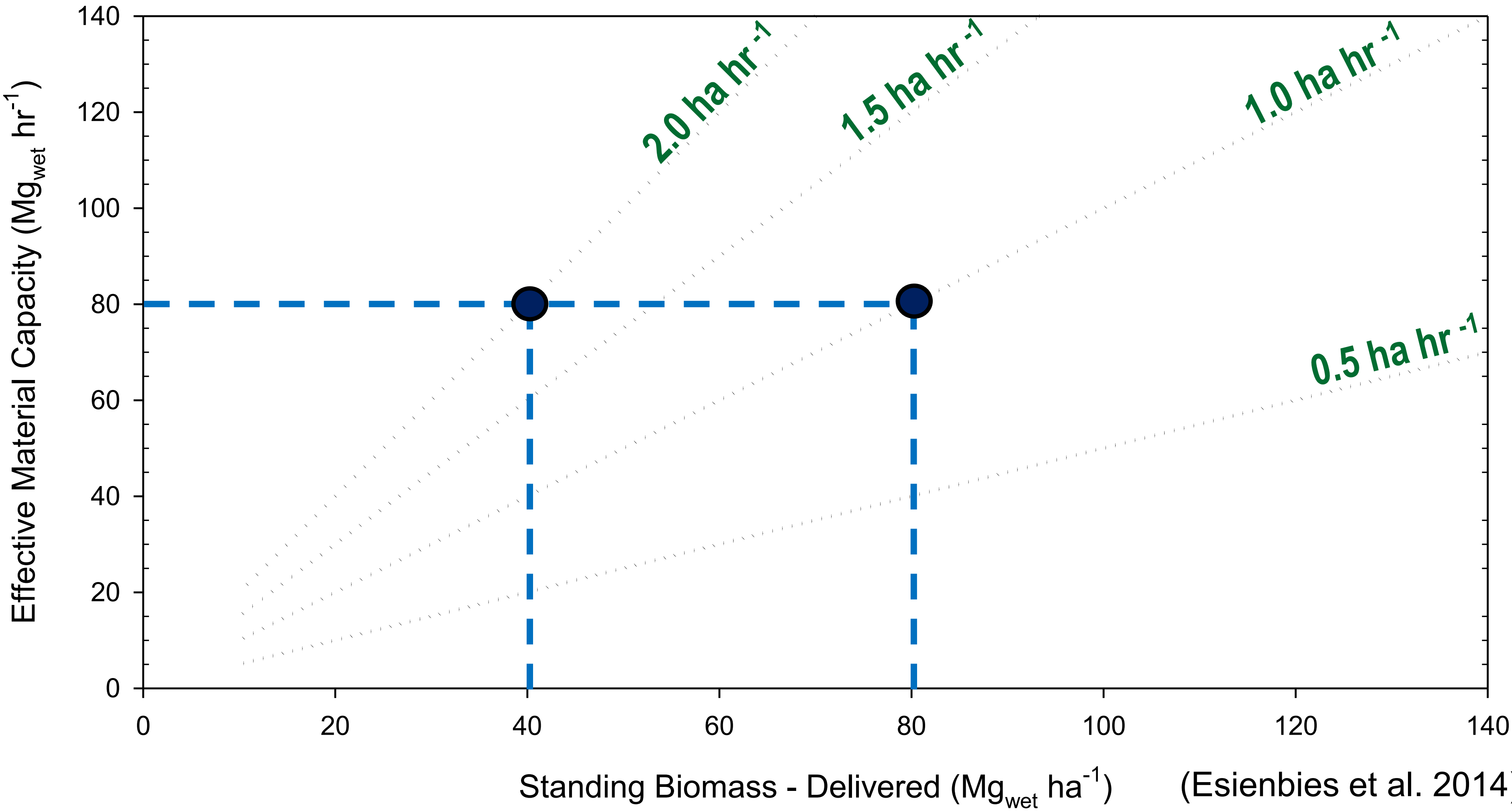
- Throughput becomes consistent over 40 Mg ha^{-1}
- Plateau likely varies with technology and conditions



(Esienbies et al. 2014)

Harvester In Field Performance

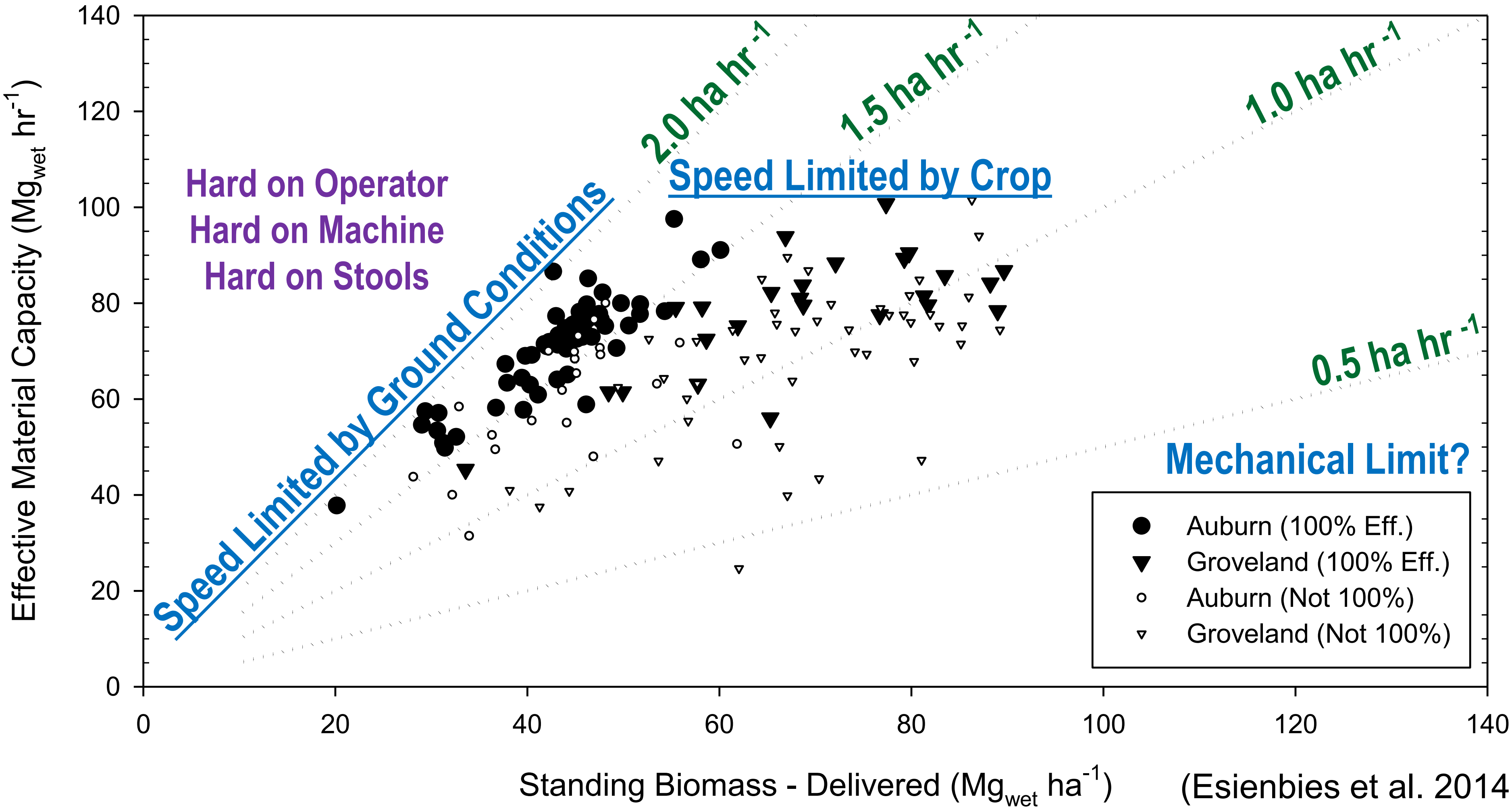
- Speed Isolines – e.g. Field Capacity to produce 80 Mg hr^{-1}
  - 2 ha hr^{-1} in 40 Mg ha^{-1}
  - 1 ha hr^{-1} in 80 Mg ha^{-1}



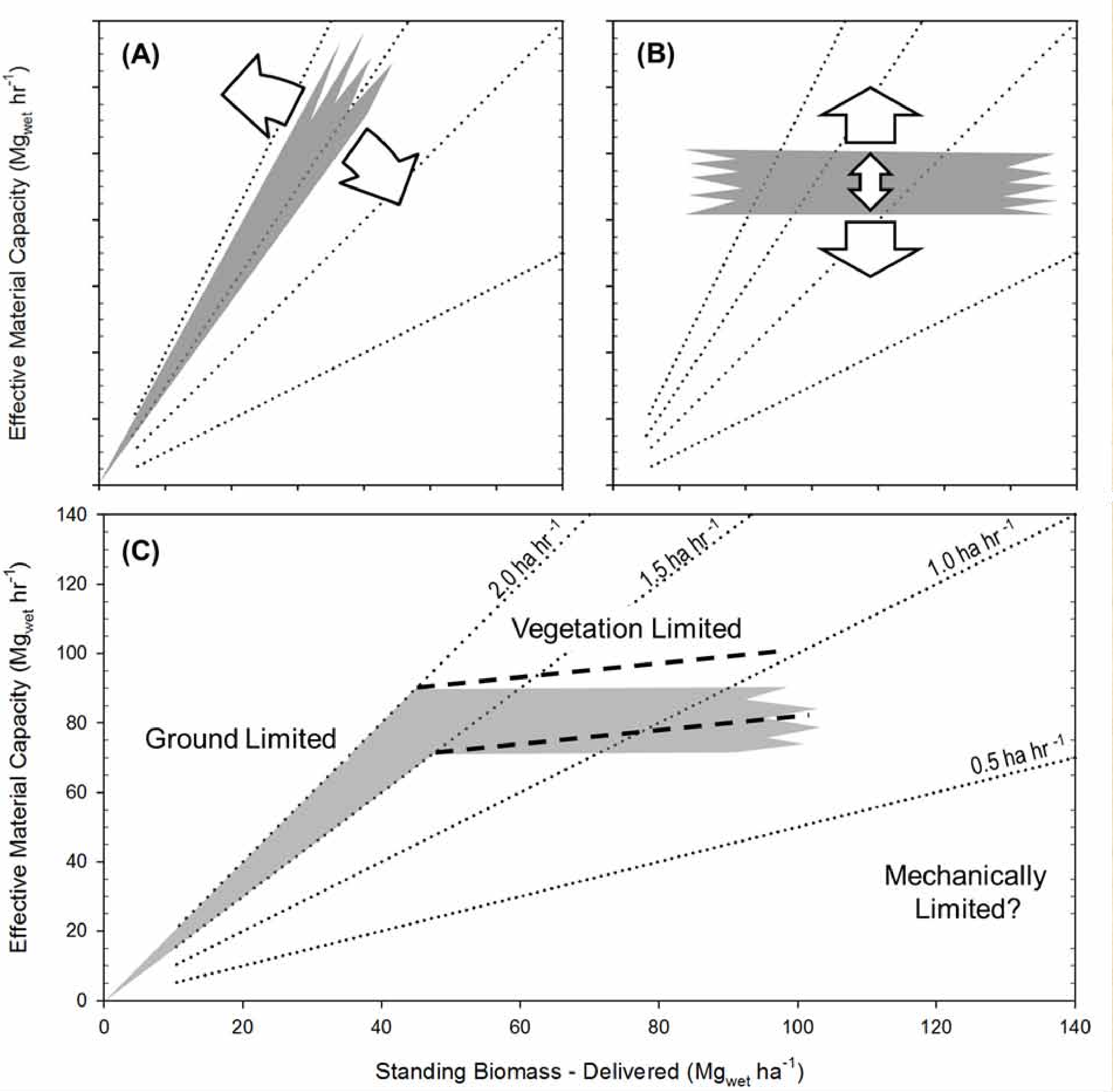
(Esienbies et al. 2014)

Harvester In Field Performance

- Standing biomass limits speed over 40 Mg ha^{-1}
  - i.e. Harvester could not go 2 ha hr $^{-1}$ in 80 Mg ha^{-1}



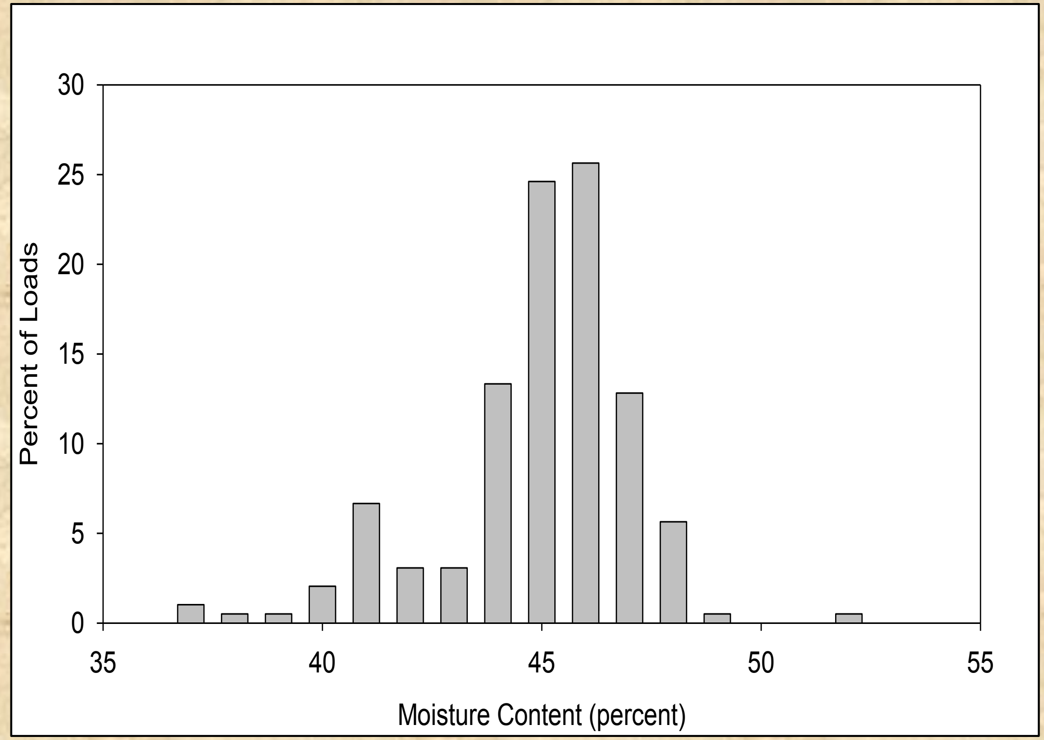
(Esienbies et al. 2014)



(Esienbies et al. 2014)

What about chip quality?

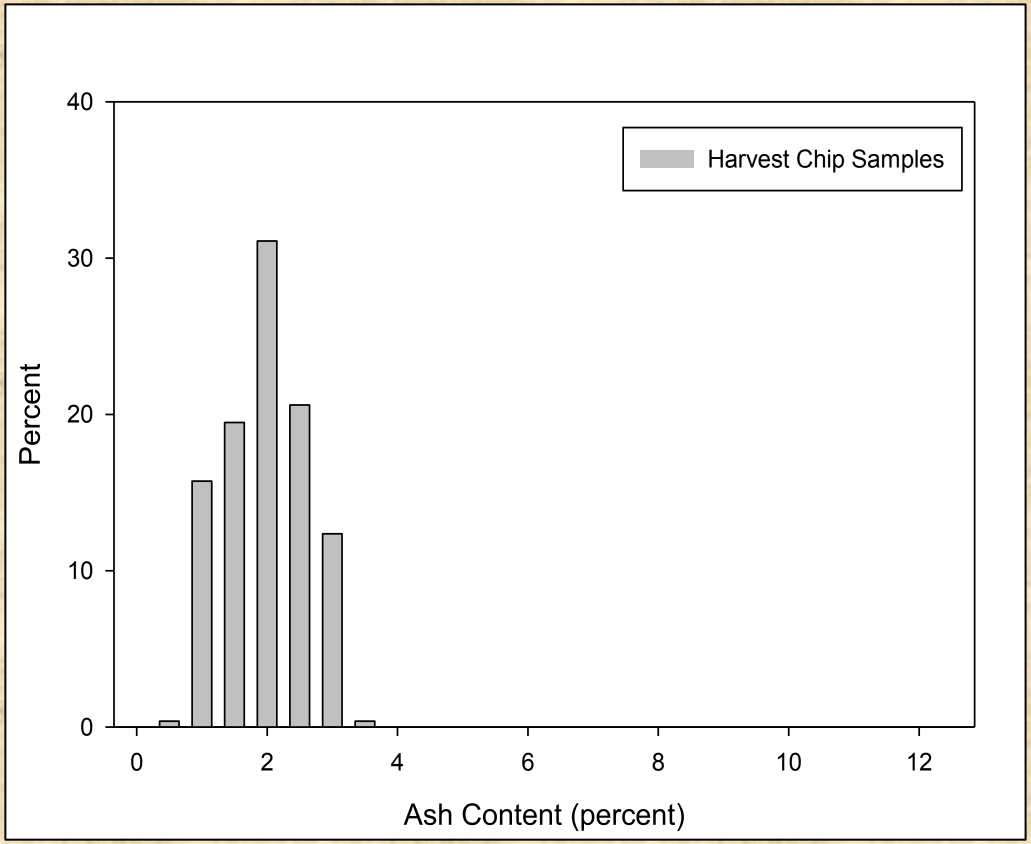
Willow Biomass Quality – Moisture



Moisture content for 195 wood chip samples collected from harvests conducted between November 2012 and February 2013.

- Moisture content of 195 harvesting trials samples was 44.4 $\pm$ 2.2% (Esienbies et al. In review)
- Only 0.5% of the samples had moisture content greater than 50%.

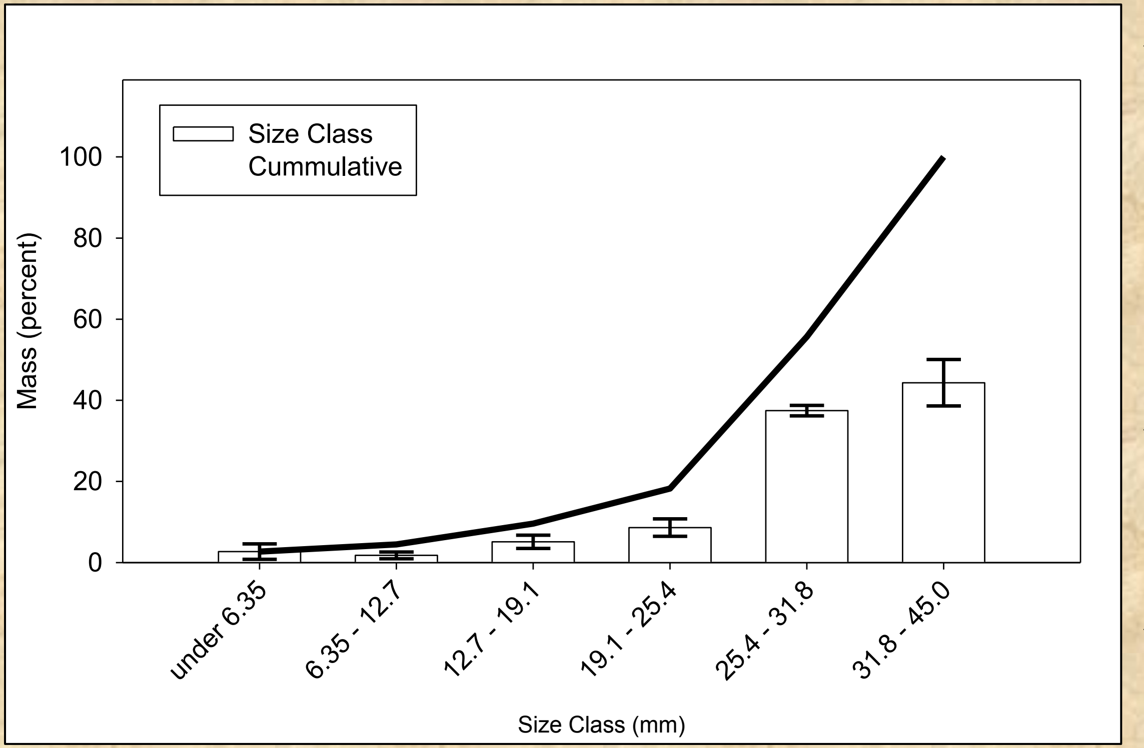
Willow Biomass Quality – Ash



Distribution of ash content of 267 willow biomass samples collected at the time of harvest in 2012/2013.

- Average ash content was 2.2 ± 0.6% (Esienbies et al. In review)
- About 12% of the samples had an ash content above 3% (ISO standard for class B1 wood chips)

Willow Biomass Quality – Particle Size



Particle size distribution of willow biomass samples collected during harvesting trials in 2012/13. Error bars indicate one standard deviation.

- More than 80% of the chips were between 25 and 45 mm (1.0 and 1.8 in) (Esienbies et al. In review)
- Less than 3% were smaller than 6.4 mm (0.25 in)
- Consistent chip sizes were produced across 14 willow cultivars and under different weather conditions

System Performance



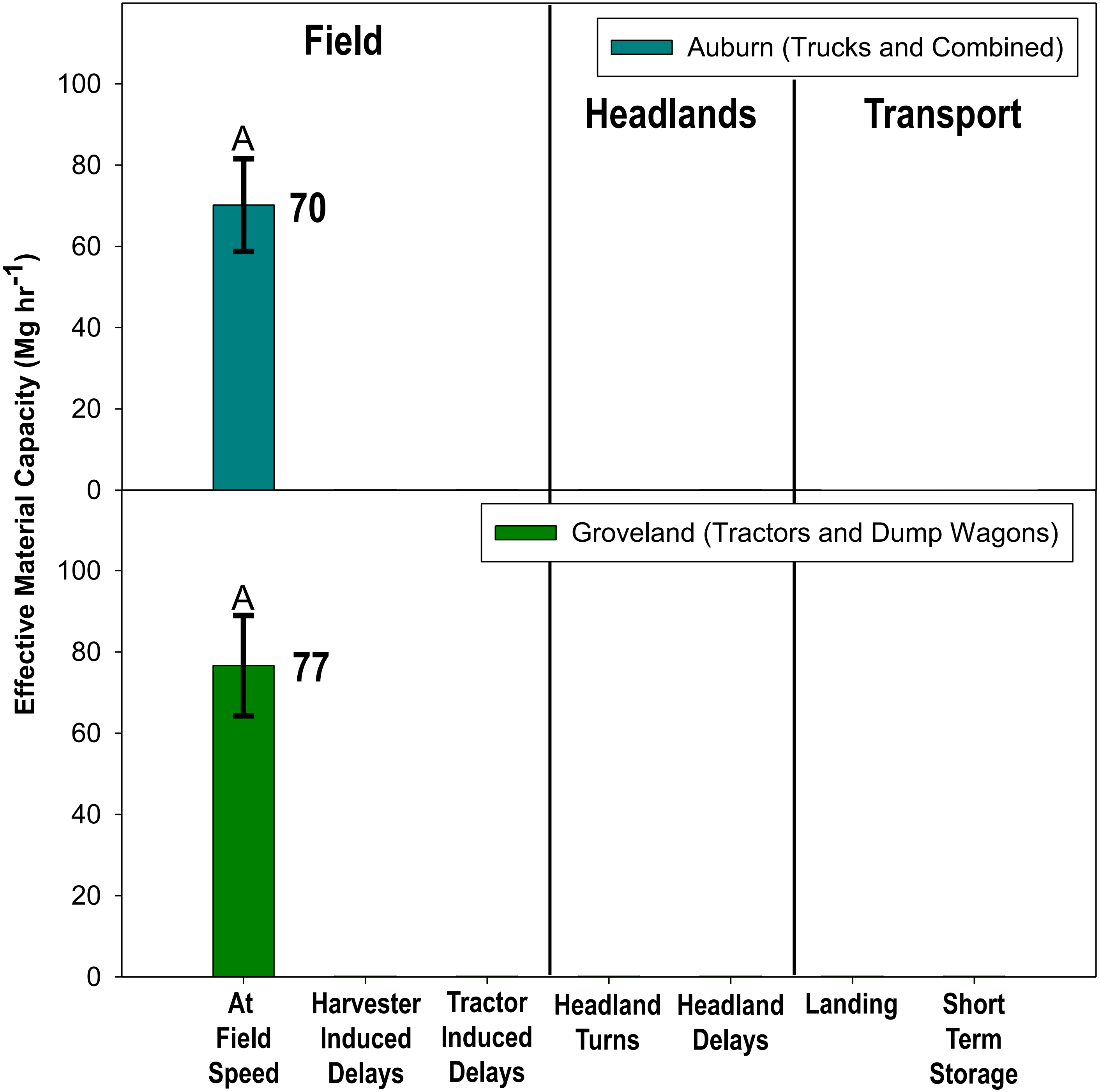



System Performance

Throughput as system components are added

Field Speed - Obs. with all delays removed (100% Eff.)

Letters indicate significant difference within site
Bars indicate std. dev.

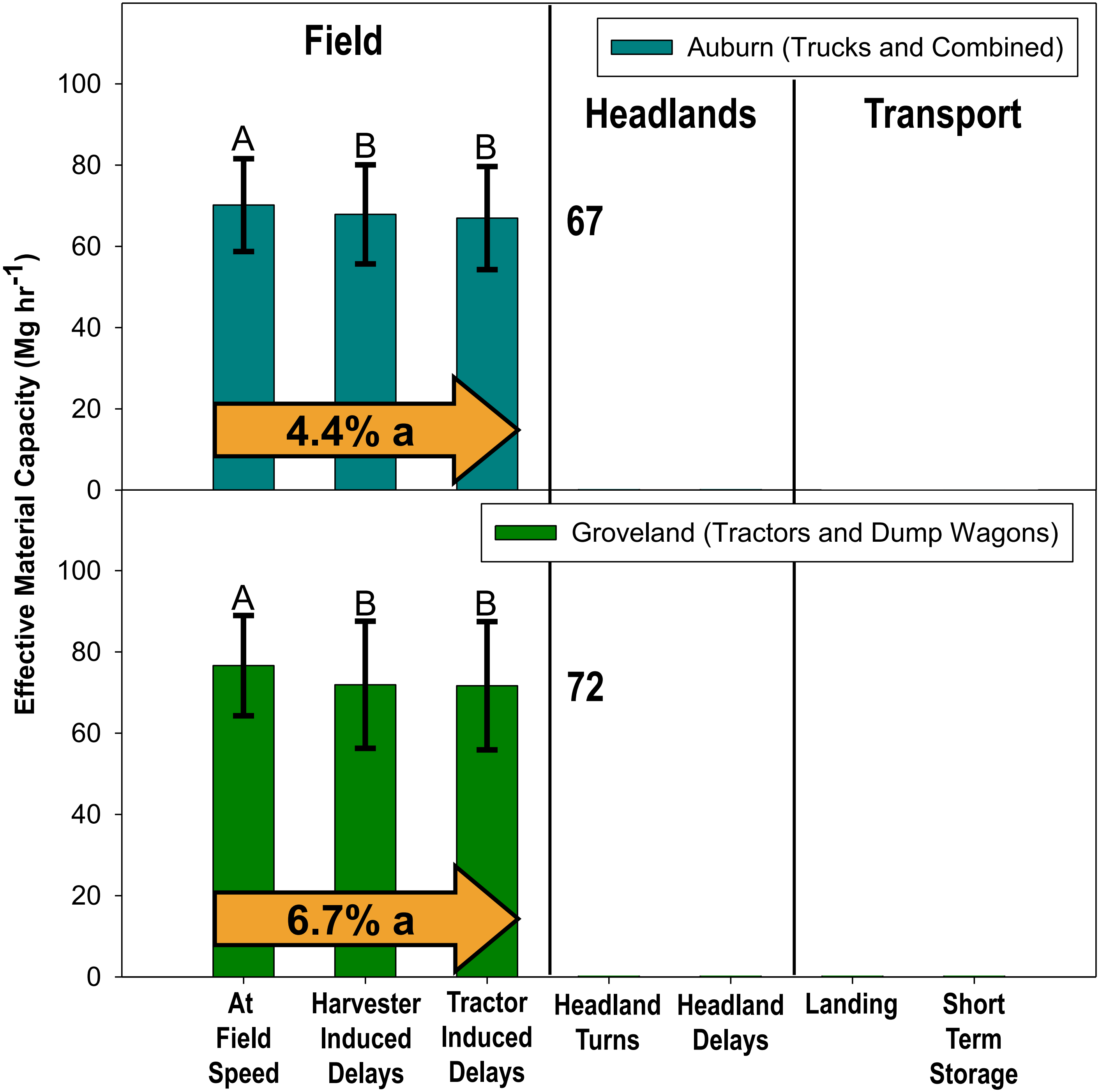


System Performance

Harvester- and Tractor-Induced Field Delays

4-7 % Loss of efficiency

Collection systems performed similarly in field

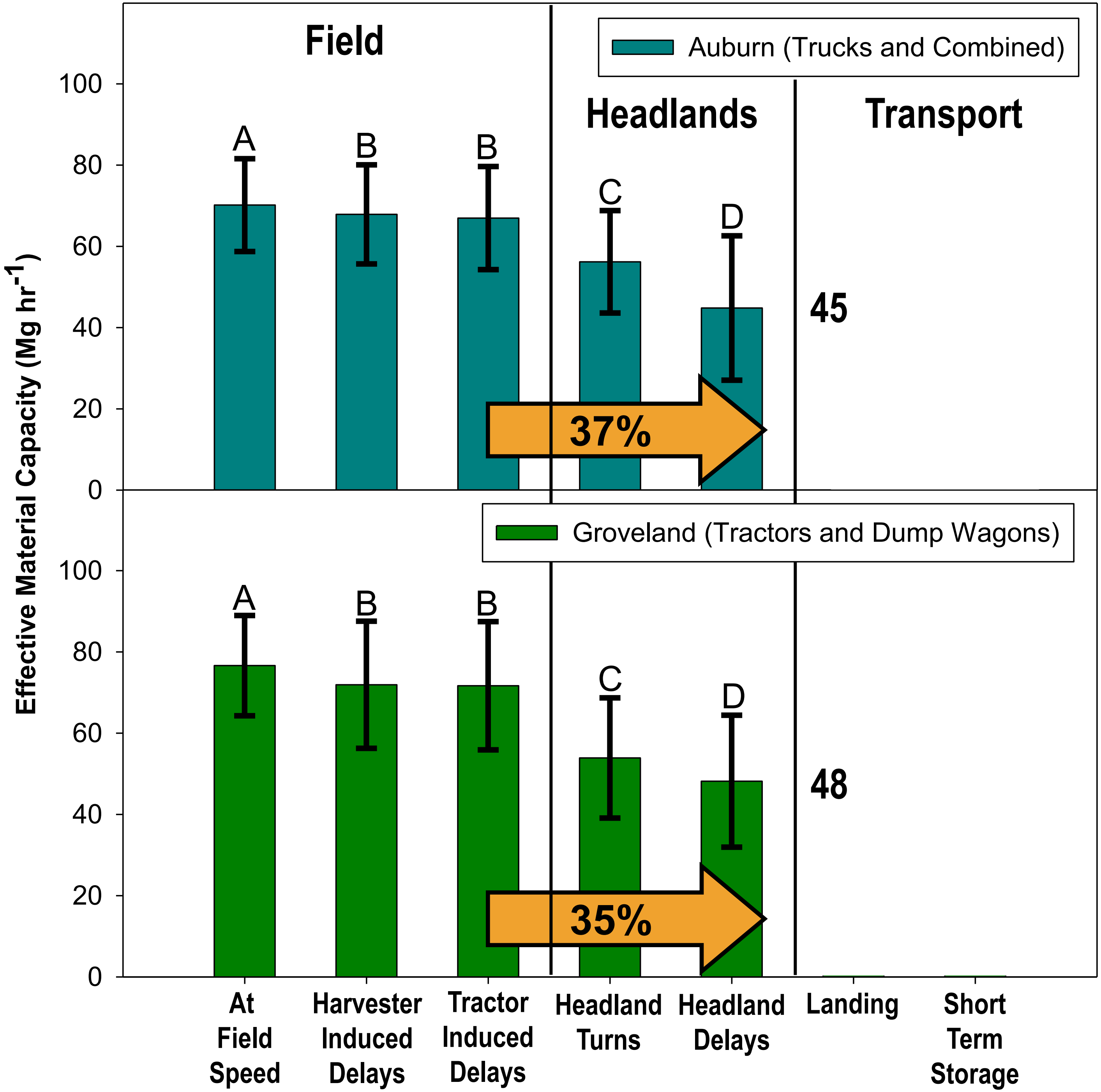


System Performance

Headland turning and delays ~36% Loss of efficiency

Auburn had direct loading into trucks and a 7-km haul resulting in waits

Limited by # of trucks

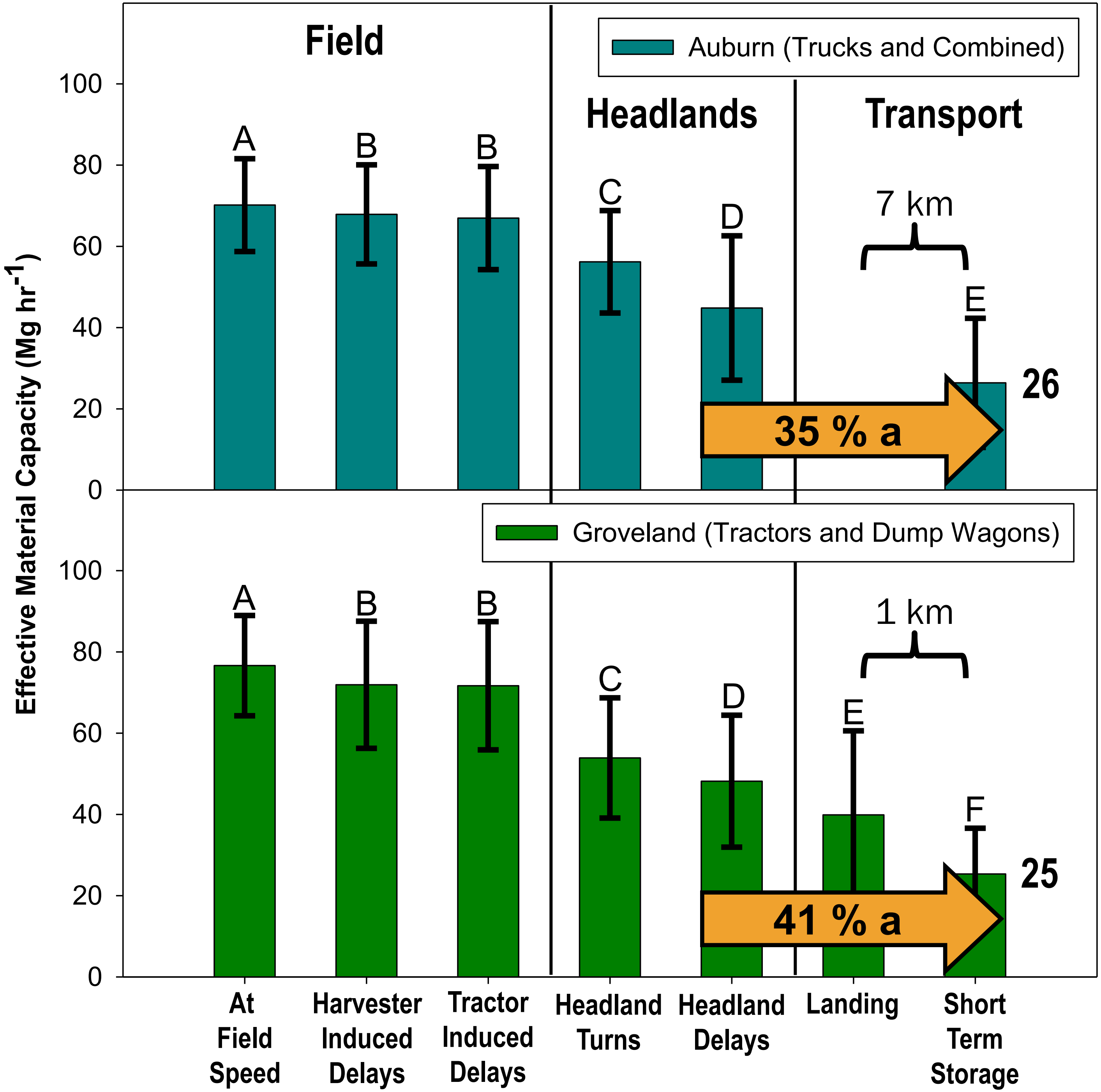


System Performance

Exchange of chips and transport to short-term storage

35-41% Loss from the headland

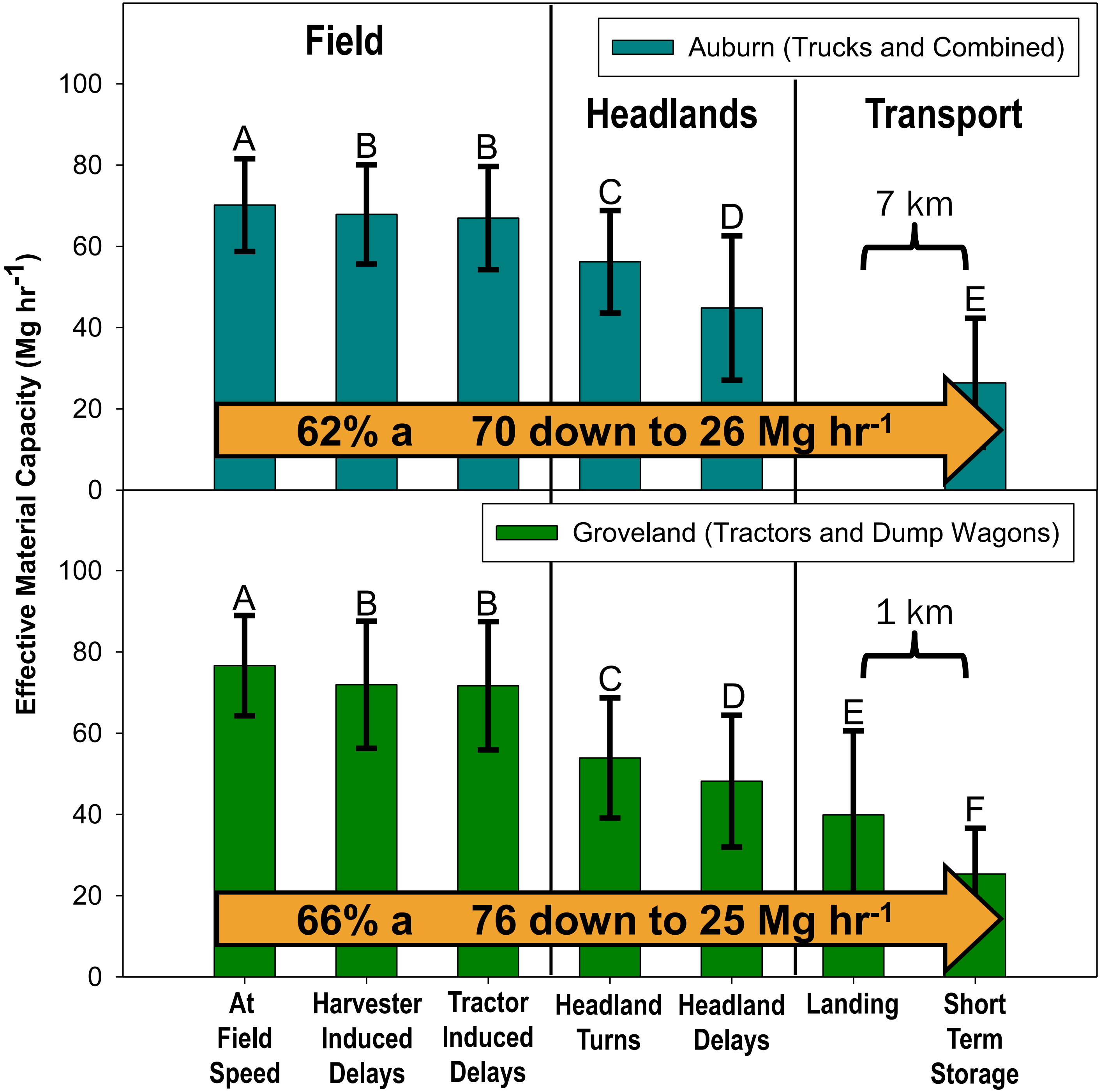
No difference between collection systems



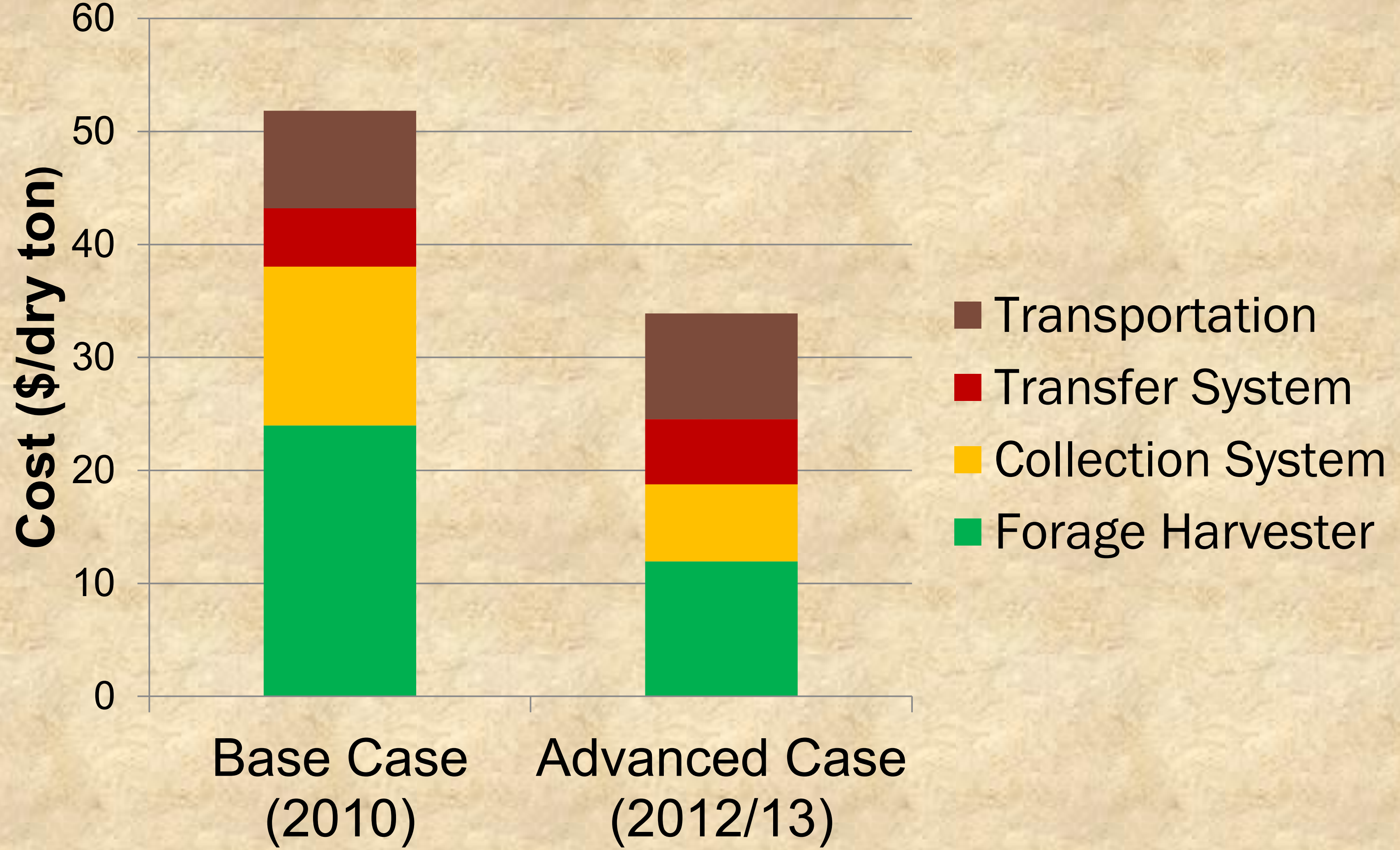
System Performance

"Out the Spout" to Storage

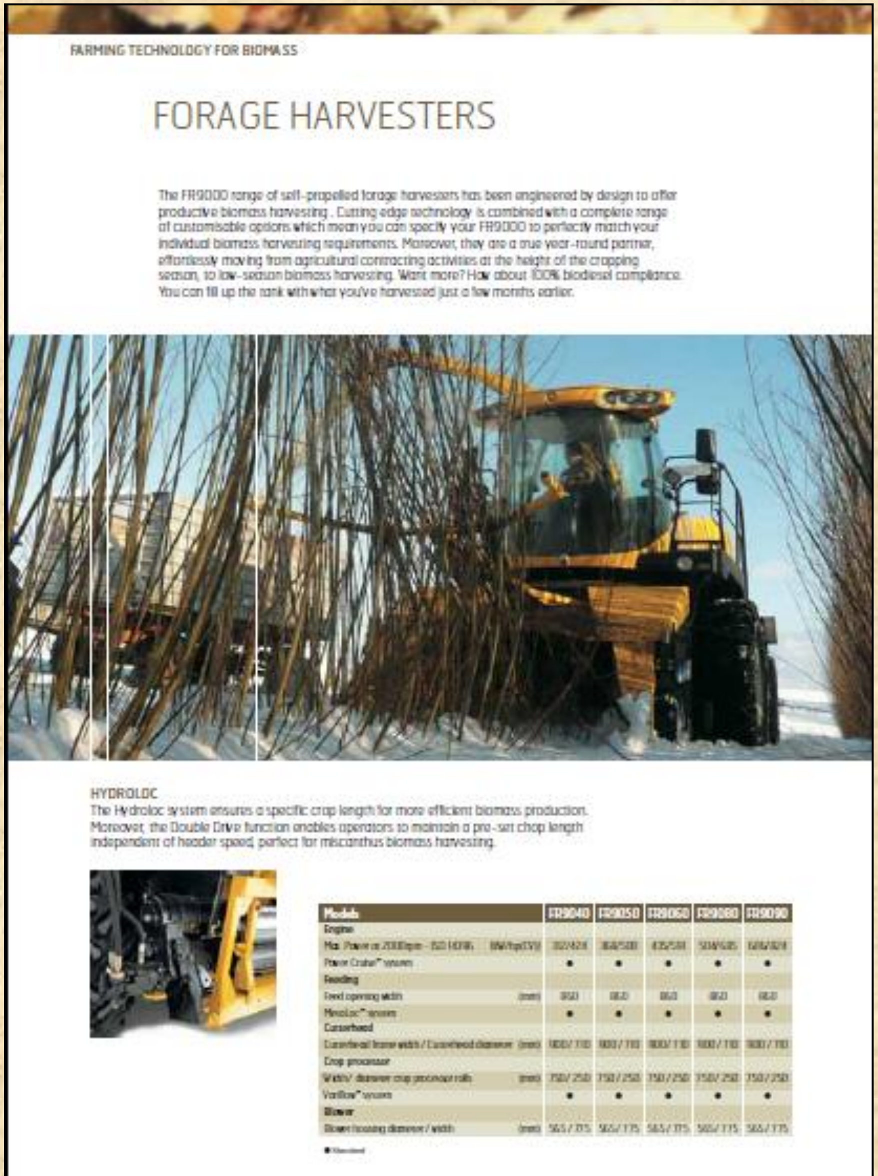
62-66% loss of efficiency overall



Harvesting Cost Reductions



Commercialization


FARMING TECHNOLOGY FOR BIOMASS

FORAGE HARVESTERS

The FR9000 range of self-propelled forage harvesters has been engineered by design to offer productive biomass harvesting. Cutting edge technology is combined with a complete range of customisable options which mean you can specify your FR9000 to perfectly match your individual biomass harvesting requirements. Moreover, they are a true year-round partner, effortlessly moving from agricultural contracting activities at the height of the cropping season, to low-season biomass harvesting. Want more? How about 100% biodiesel compliance. You can fill up the tank with what you've harvested just a few months earlier.

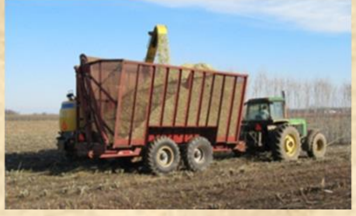
HYDROLOC

The Hydroloc system ensures a specific crop length for more efficient biomass production. Moreover, the Double Drive function enables operators to maintain a pre-set chop length independent of header speed, perfect for miscanthus biomass harvesting.

Models		FR9040	FR9050	FR9060	FR9080	FR9090
Engine						
Max. Power at 2000rpm - ISO 14396	kW/hp(CV)	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Power Cruise™ system		●	●	●	●	●
Feeding						
Feed opening width	(mm)	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
MetaLoc™ system		●	●	●	●	●
Cutterhead						
Cutterhead frame width / Cutterhead diameter	(mm)	900 / 710	900 / 710	900 / 710	900 / 710	900 / 710
Crop processor						
Width/ diameter crop processor rolls	(mm)	750 / 250	750 / 250	750 / 250	750 / 250	750 / 250
Variflow™ system		●	●	●	●	●
Blower						
Blower housing diameter / width	(mm)	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

● Standard

- New Holland has approved woody crop header for use on FR series forage harvesters
- Network of dealers in North America and Europe now sell and support woody crop harvester
- Units sold in both U.S. and Europe



Conclusions Regarding the System

- Harvester is reliable and predictable
  - Over 70 Mg_{wet} hr^{-1} on areas with over 40 Mg_{wet} ha^{-1}
- Quality of woody biomass produced is consistent
- Harvesting costs were reduced by 35%
- Harvester is supported by New Holland dealers
- Field logistics and the collection system remains a limiting factor
  - Over 60% loss in efficiency
  - Field maneuverability, landing transfers & distance to storage

Challenges Ahead

- Improve collection system and match it to the harvester
- Optimize logistics to address collection and storage issues (i.e. IBSAL and BLM models)
- Integrating SRWC biomass supply with other forest-based biomass logistics chains
- Improve real-time monitoring

Questions

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