Does Wood-based Electricity Generation Reduces GHG Emissions? An Exploration Considering Forestland Holdings, Harvest Age, and Power Plant Capacities

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Outline

1. Introduction
2. Methods
3. Results
4. Discussions
5. Conclusions

Brief Summary

- Size of forest landholding impacts GHGs
- Feedstock types (LR vs. LR & PW) affects GHGs
- GHGs increase with an increase in harvest age
- GHG emissions of a large capacity wood-based power plant might be greater than an equivalent coal-based power plant.

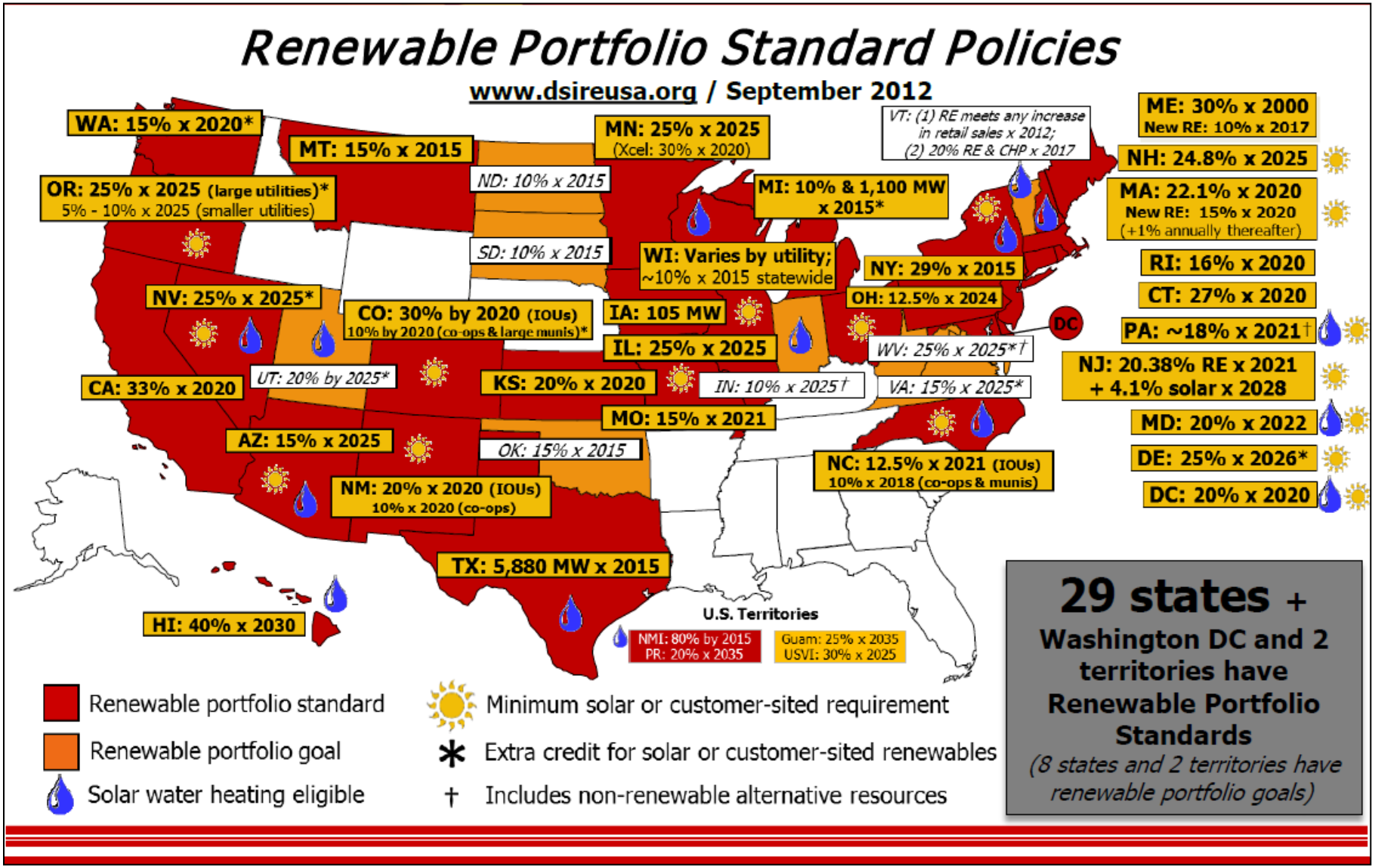
Introduction

Electricity and GHG Emissions

- GHG emissions in 2010: About 6822 million metric tons CO_2e
- Energy-related GHG emissions in 2010: About 5933 million metric tons CO_2e (87%)
- Electricity sector GHG emissions: 2314 million metric tons CO_2e (34%)

USEPA. Inventory of US Greenhouse Gas Emissions and Sinks: 1990 – 2010. (United States Environment Protection Agency, Washington, DC, 2012).

Policy Initiatives

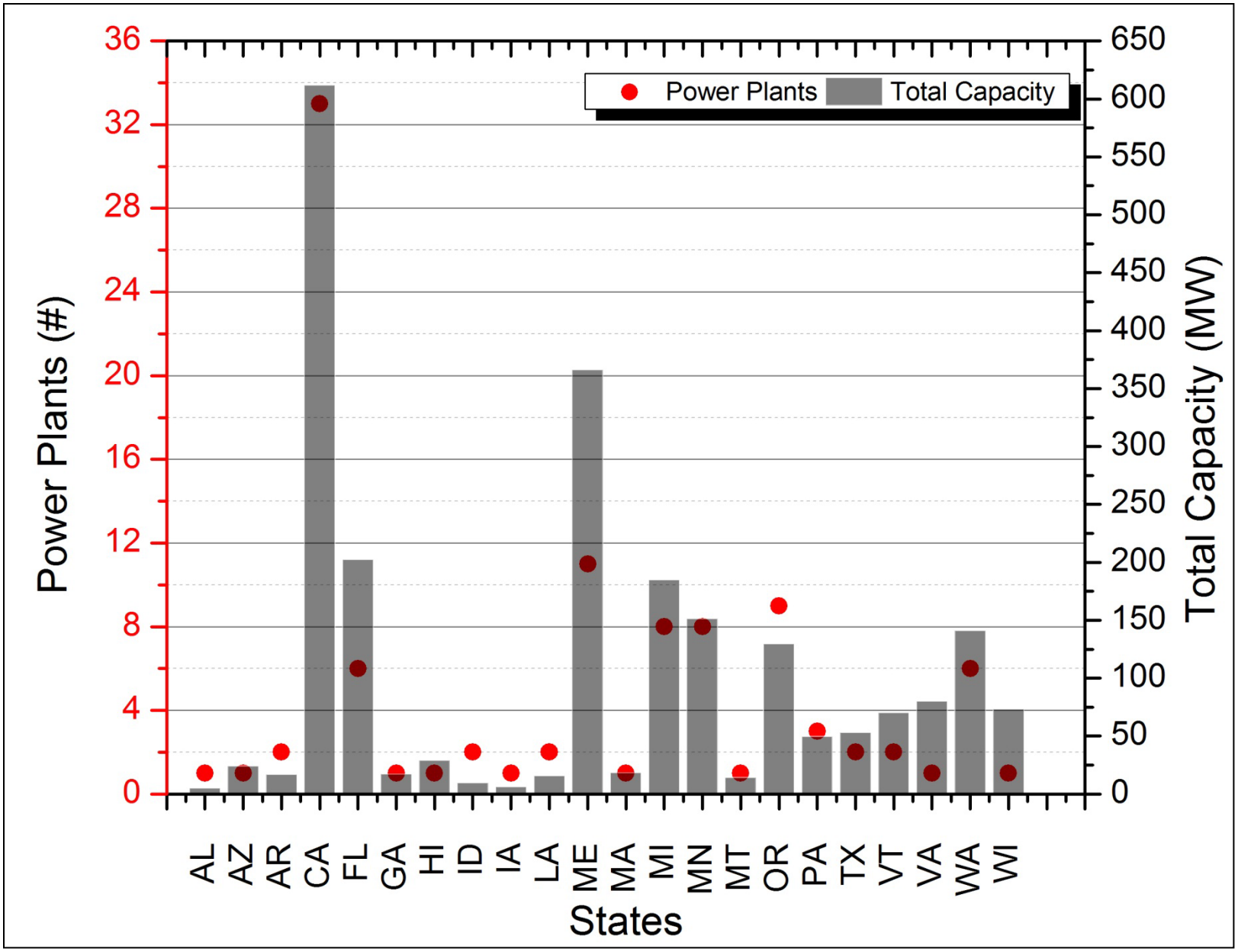


Policy Initiatives

- Renewable Electricity Production Tax Credit
- Investment Tax Credit

Peak generation capacity of biomass based electricity will increase from 11.51 to 49.28 billion kWh between 2010 and 2035.

USEIA. Annual Energy Outlook 2012 with Projections to 2035. (Washington, DC, 2012).



BPA. *US Biomass Facilities*, <http://www.usabiomass.org/docs/biomass_map.pdf> (2012)

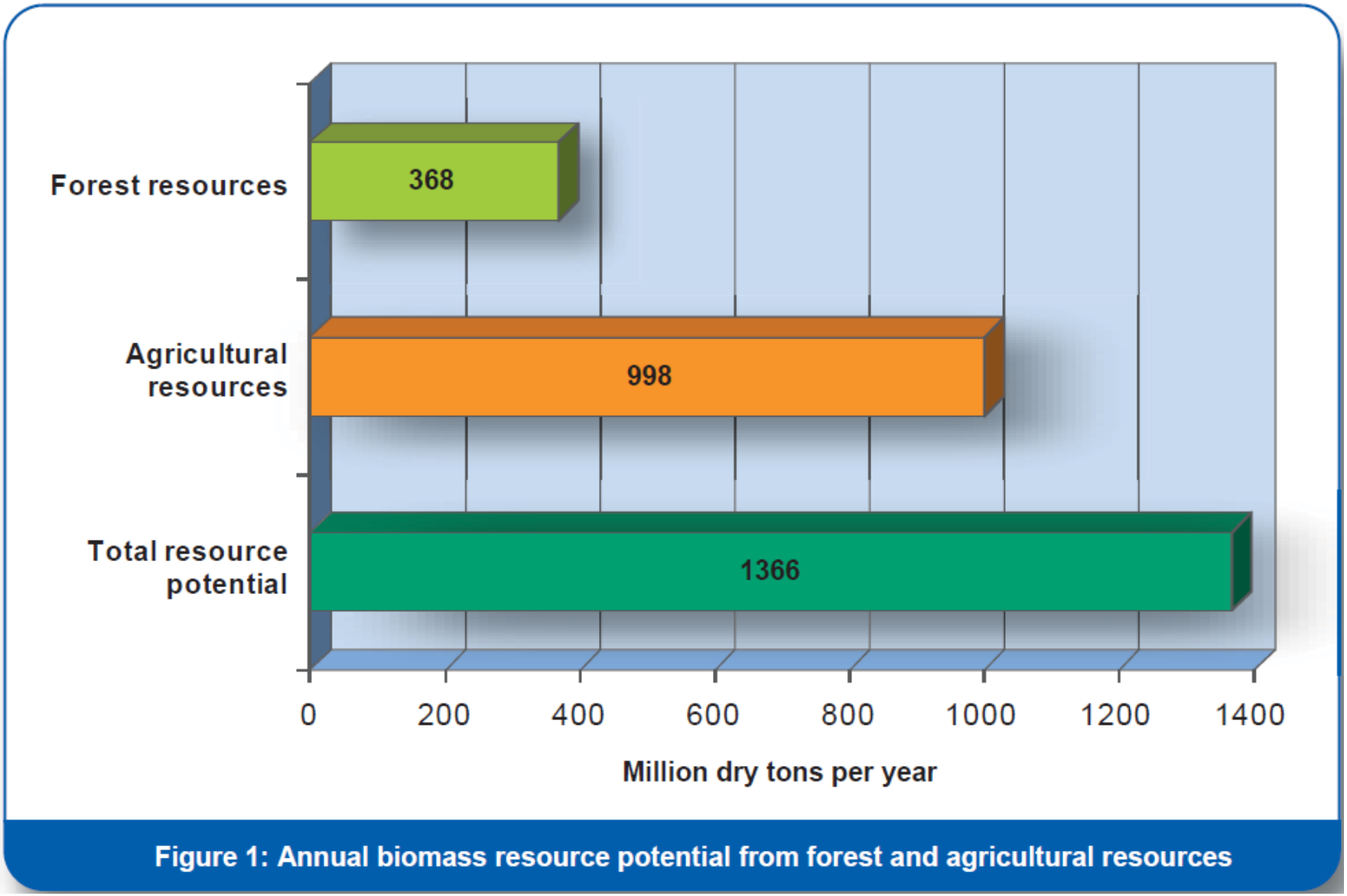


Figure 1: Annual biomass resource potential from forest and agricultural resources

Perlack, R. *et al.* Biomass as a feedstock for a bioenergy and bioproducts industry: The technical feasibility of a billion-ton annual supply. (Oak Ridge National laboratory, United States Department of Energy/United States Department of Agriculture, Washington, D.C., 2005)

Changes in Forestland Holdings

	NIPF Area (1,000 acres)			NIPF owners (1,000)		
Average Forestland Holding	1993	2003	2006	1993	2003	2006
1-9 acres	15,847	19223	20,661	5583	6159	6821
10-49 acres	56,180	61613	61066	2566	3028	2961
50-99 acres	42,521	41372	44,020	647	623	683
Sub-total	114,548	122,208	125,747	8,796	9,810	10,465
100-499 acres	77,137	85697	91,070	479	487	557
500-999 acres	17,015	20330	25578	29	9	45
1000-4999 acres	17,051	24,021	42,229	12	27	28
5000+ acres	6,596	9,382	43,926	3	14	10
Sub-total	117,799	139,430	202,803	523	537	640
Total	232,347	261,638	328,550	9319	10347	11105

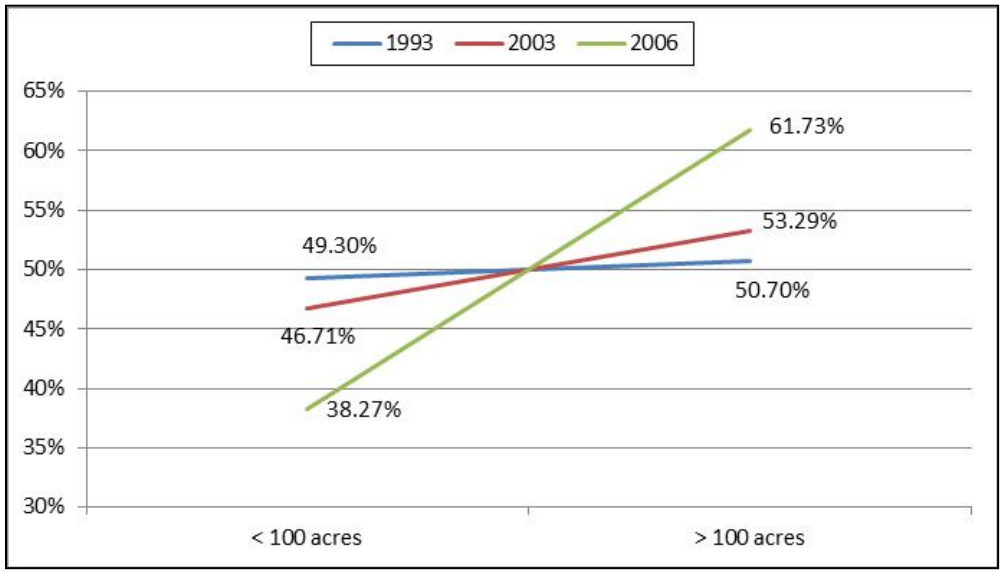
Butler, B. Family Forest Owners of the United States, 2006. (Northern Research Station, United States Department of Agriculture, Forest Service, Newtown Square, PA, 2008).

Birch, T. Private forest-land owners of the United States, 1994. (Northeastern Forest Experiment Station, United States Department of Agriculture, Forest Service, Radnor, PA, 1996).

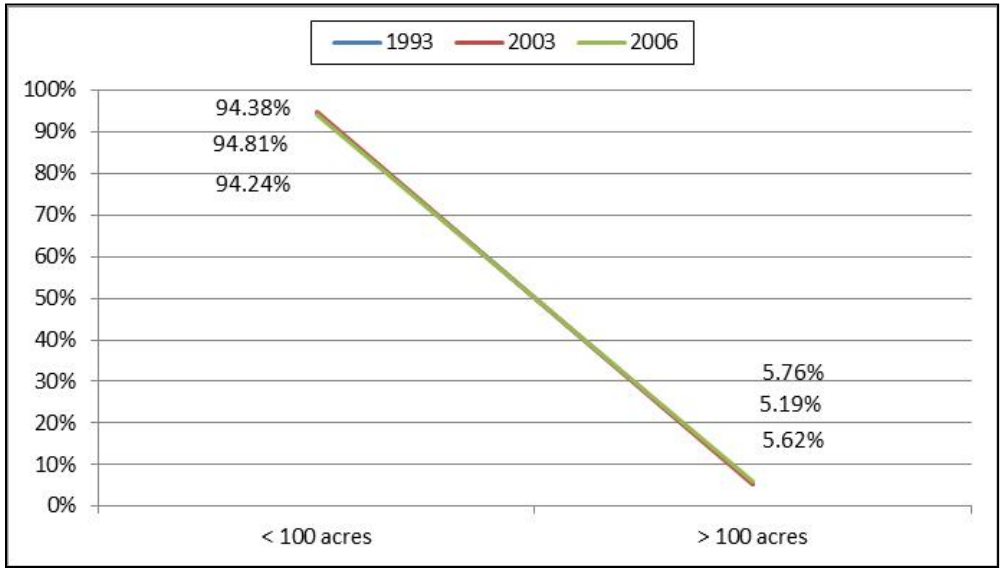
Butler, B. & Leatherberry, E. America's family forest owners. *Journal of Forestry* **102**, 4-9 (2004)

Changes in Forestland Holdings

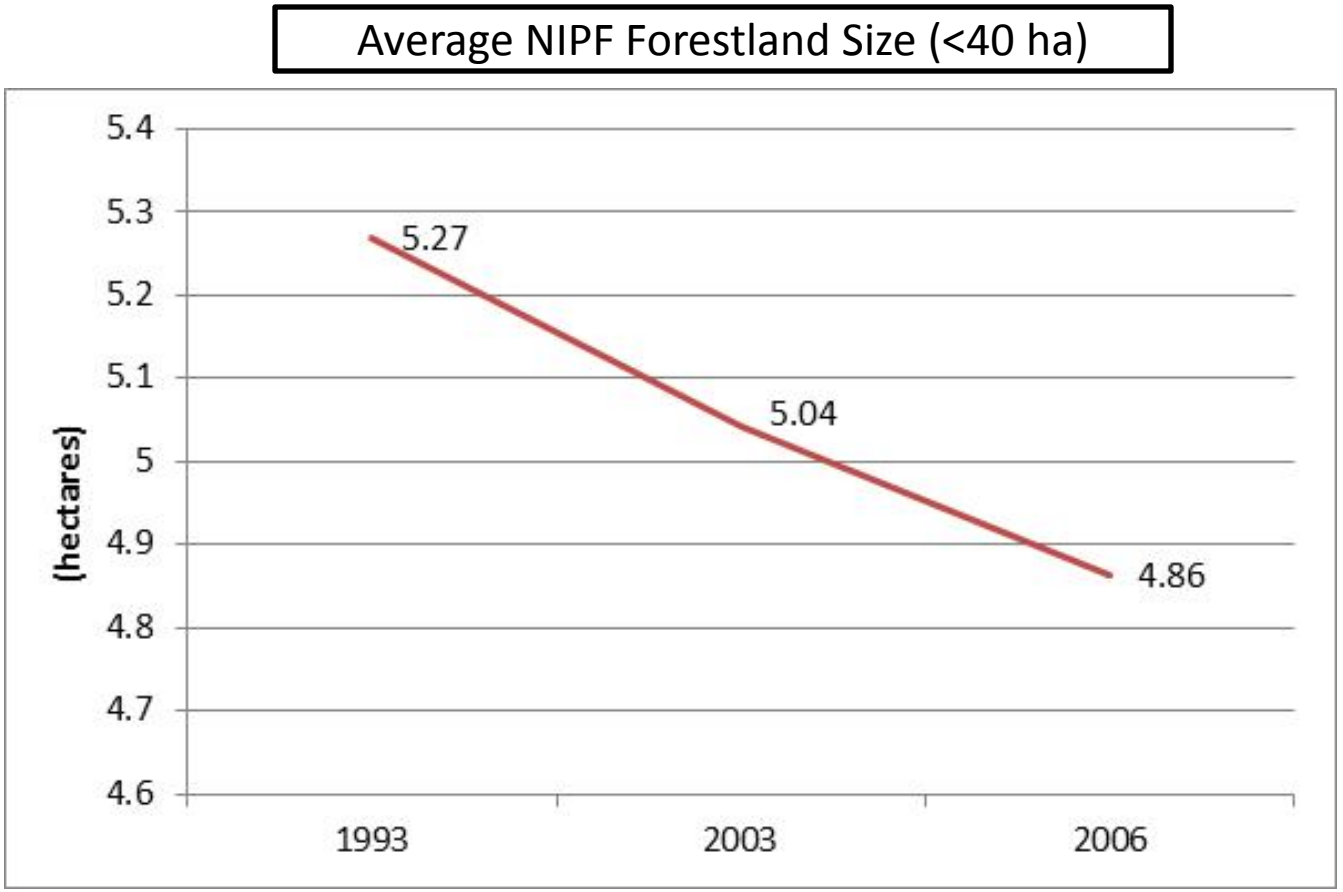
Forestland Area



NIPF landowners



Changes in Forestland Holdings



Existing Studies

- Kumar et al. (2003) Biomass & Bioenergy **24**, 445-464.
  - Optimal power plant size
- Gan (2007) Energy Policy **35**, 6003-6009.
  - Economics of biopower generation excluding carbon
- Manomet Center for Conservation Sciences (2010).
  - Long payback period before any significant carbon benefits
- Dwivedi et al. (2011) BioEnergy Research **4**, 180-192.
- Magellie et al. (2009) Biomass & Bioenergy **33**, 434-441
  - Immediate significant carbon benefits

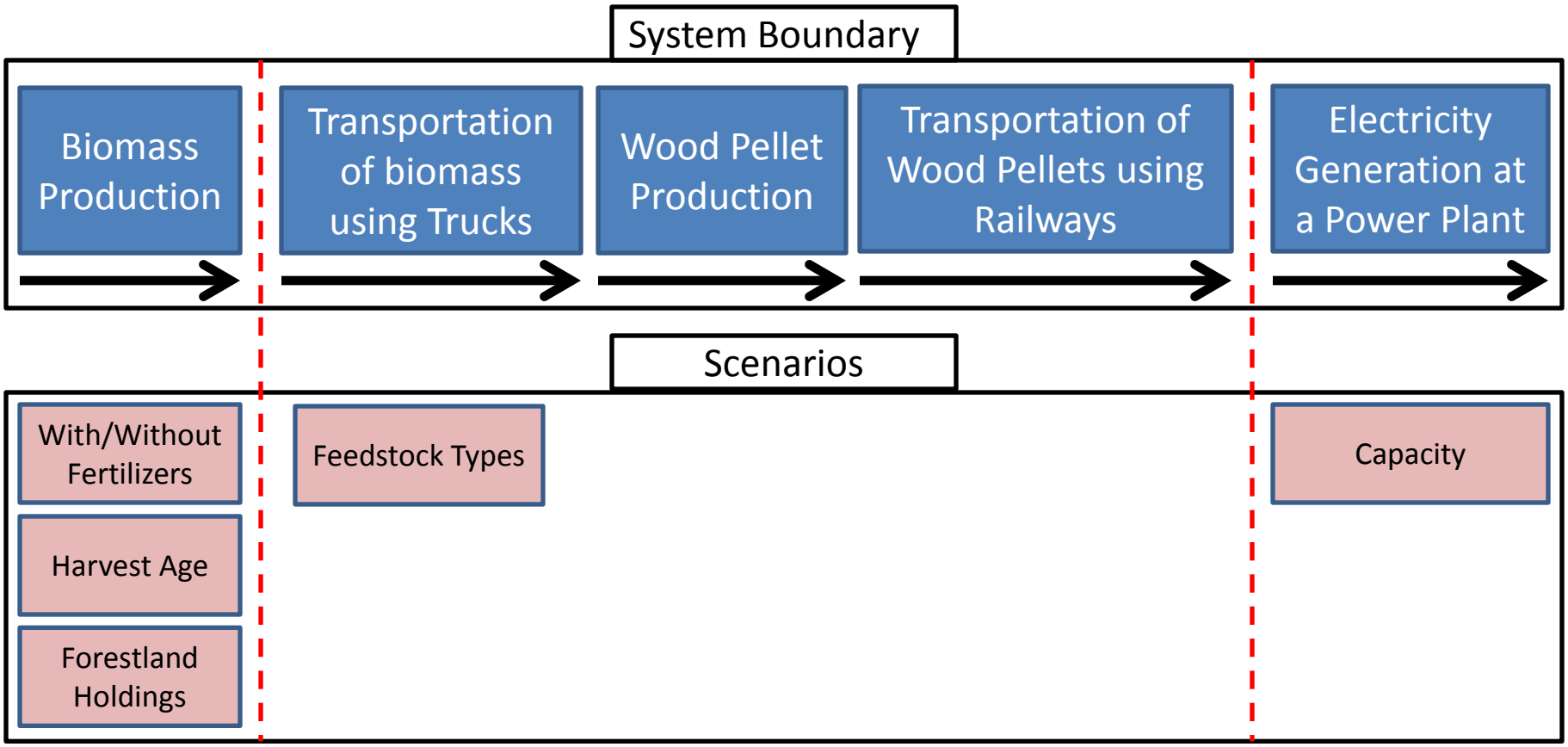
Research Objectives

- To analyze impact of forestland holdings, harvest age, and feedstock types on the overall GHG emissions
- To estimate relative savings in GHG emissions with respect to a comparative coal-based power plant

Methods

Methods

- Reference species: Slash pine (*Pinus elliottii*)
  - Yin et al. (1998)



Methods

Wood Pellets Required

$$WP_{req} = [P \mathbf{X} (CF/100) \mathbf{X} 8760] / [(CV_{WP}/3.6) \mathbf{X} (CE/100)]$$

P is the capacity of power plant in MW,
CF is the power plant capacity factor in percentage,
CV_{WP} is the calorific value of wood pellets in MJ/kg, and
CE is efficiency of converting heat into electricity in percentage.

Biomass Required

$$GB_{req} = WP_{req} \mathbf{X} (1- (MC_{WP}/100)) \mathbf{X} (1+ (MC_{SP}/100)) \mathbf{X} (100/ (100 - BK))$$

MC_{WP} is the moisture content of wood pellets in percentage on oven dry basis,
MC_{SP} is the moisture content of slash pine in percentage on oven dry basis, and
BK is the percentage of bark weight.

Methods

Square Forest Parcels Required

$$FP_{tot} = GB_{req} / (Bio_{unit} \mathbf{X} LH_{size})$$

Bio_{unit} is the biomass available for electricity production in metric tons/hectare, and LH_{size} is the average size of forestland holding in hectares.

Side length of the square woodshed

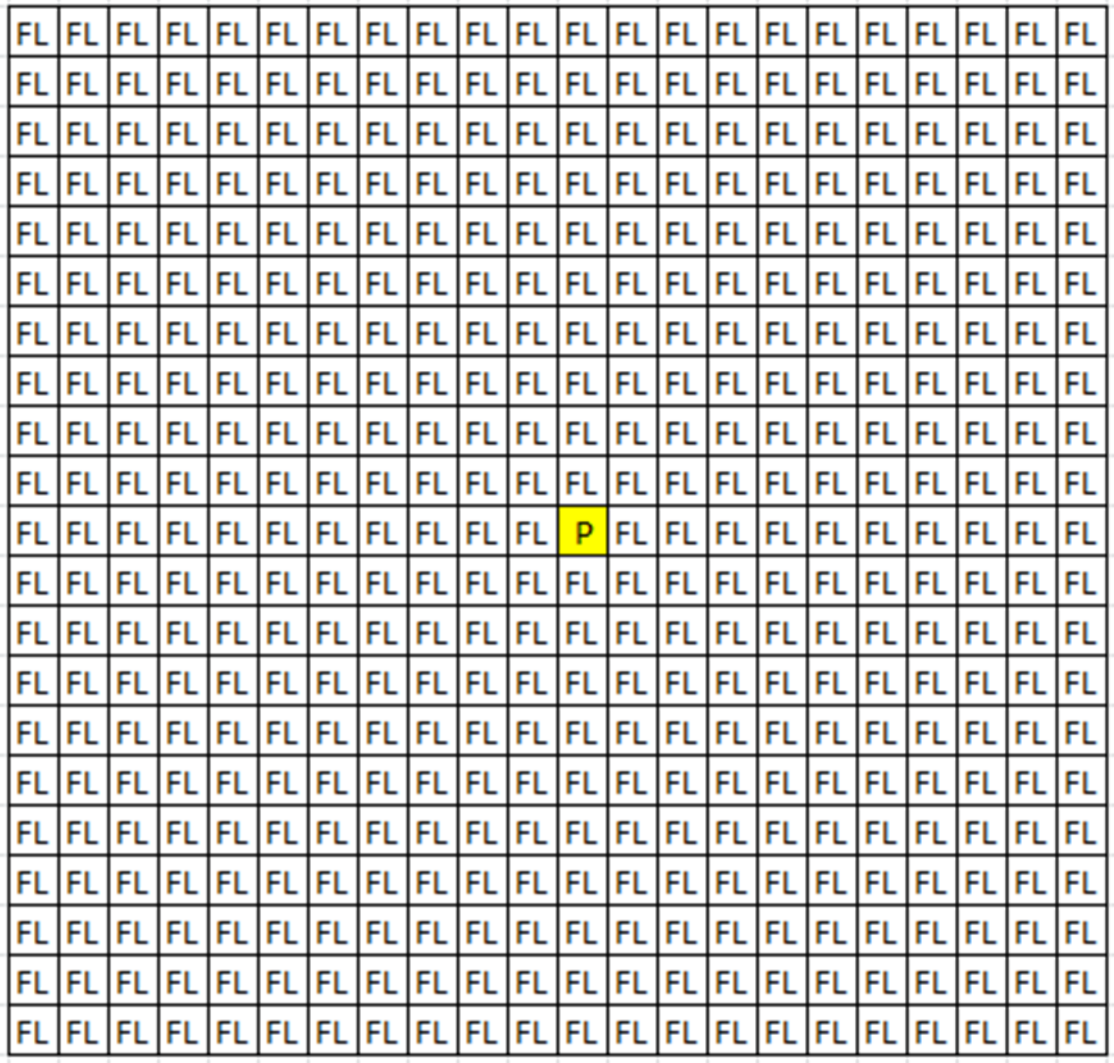
$$WS_{side} = sqrt(FP_{tot}) \mathbf{X} 2) + 1$$

Optimization Rule

$$min. \sum_{i=1}^{i=k} X_i D_i \text{ , such that } X_i \text{ is binary } (0, 1) \text{ and } X_i B_i \geq GB_{req}$$

k = WS_{num} **X** WS_{num} – 1,
B_i = Bio_{unit} **X** LH_{size}, and
D is the distance of each forest parcel from the power plant

Forested Landscape



Forested Landscape

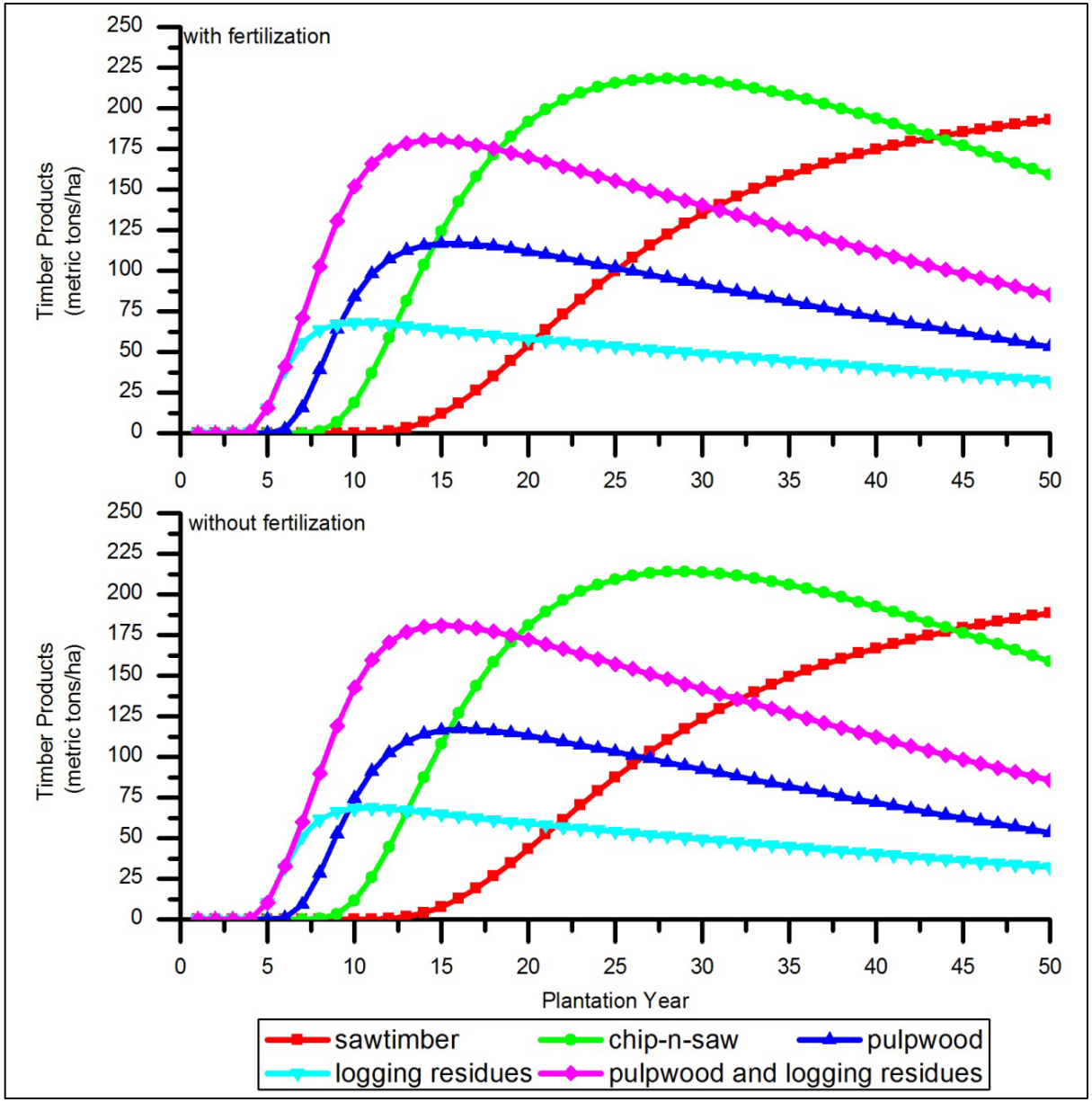
FL	FL	FL	FL	FL	FL	FL
FL	FL	FL	FL	FL	FL	FL
FL	FL	FL	FL	FL	FL	FL
FL	FL	FL	P	FL	FL	FL
FL	FL	FL	FL	FL	FL	FL
FL	FL	FL	FL	FL	FL	FL
FL	FL	FL	FL	FL	FL	FL

Life Cycle Assessment

- ISO guidelines
- Functional Unit: A unit of electricity
- Carbon Management
  - No soil carbon
  - No biogenic carbon

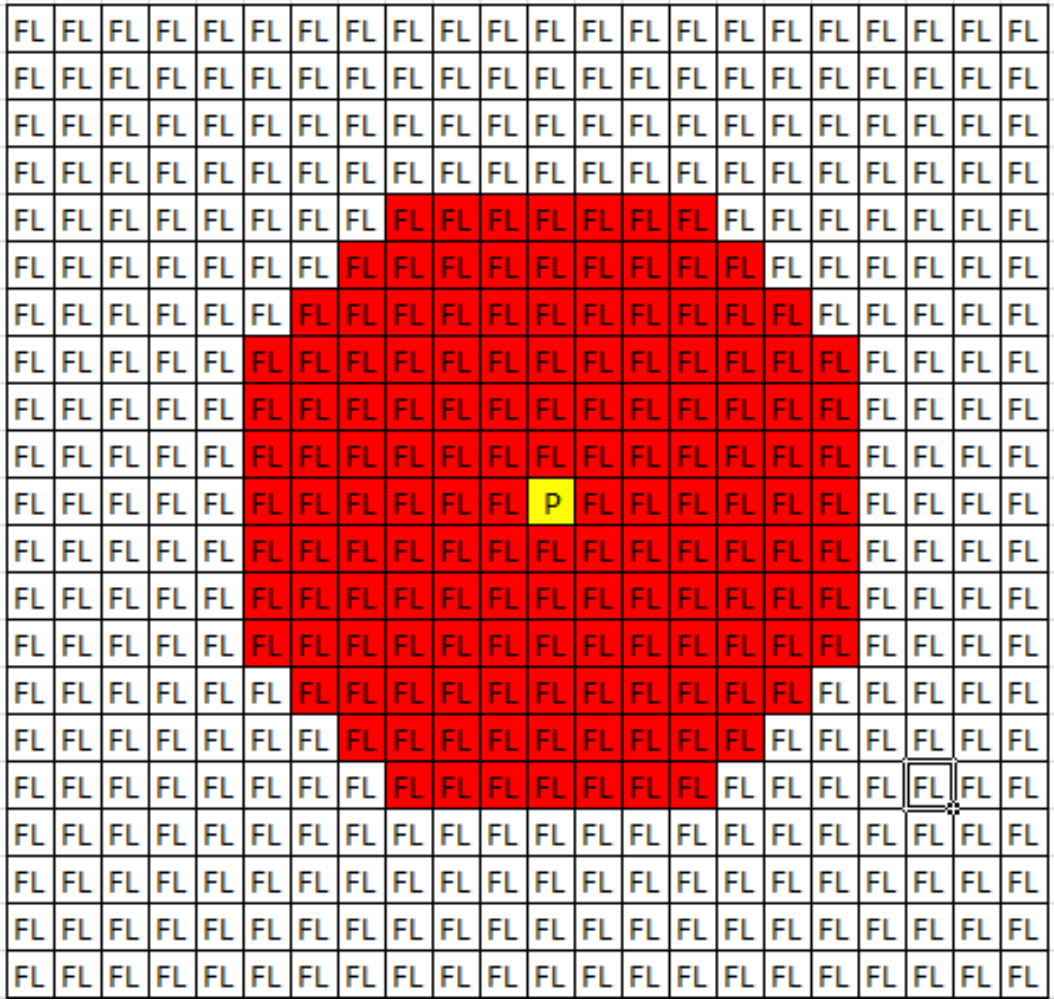
Results

Biomass Growth

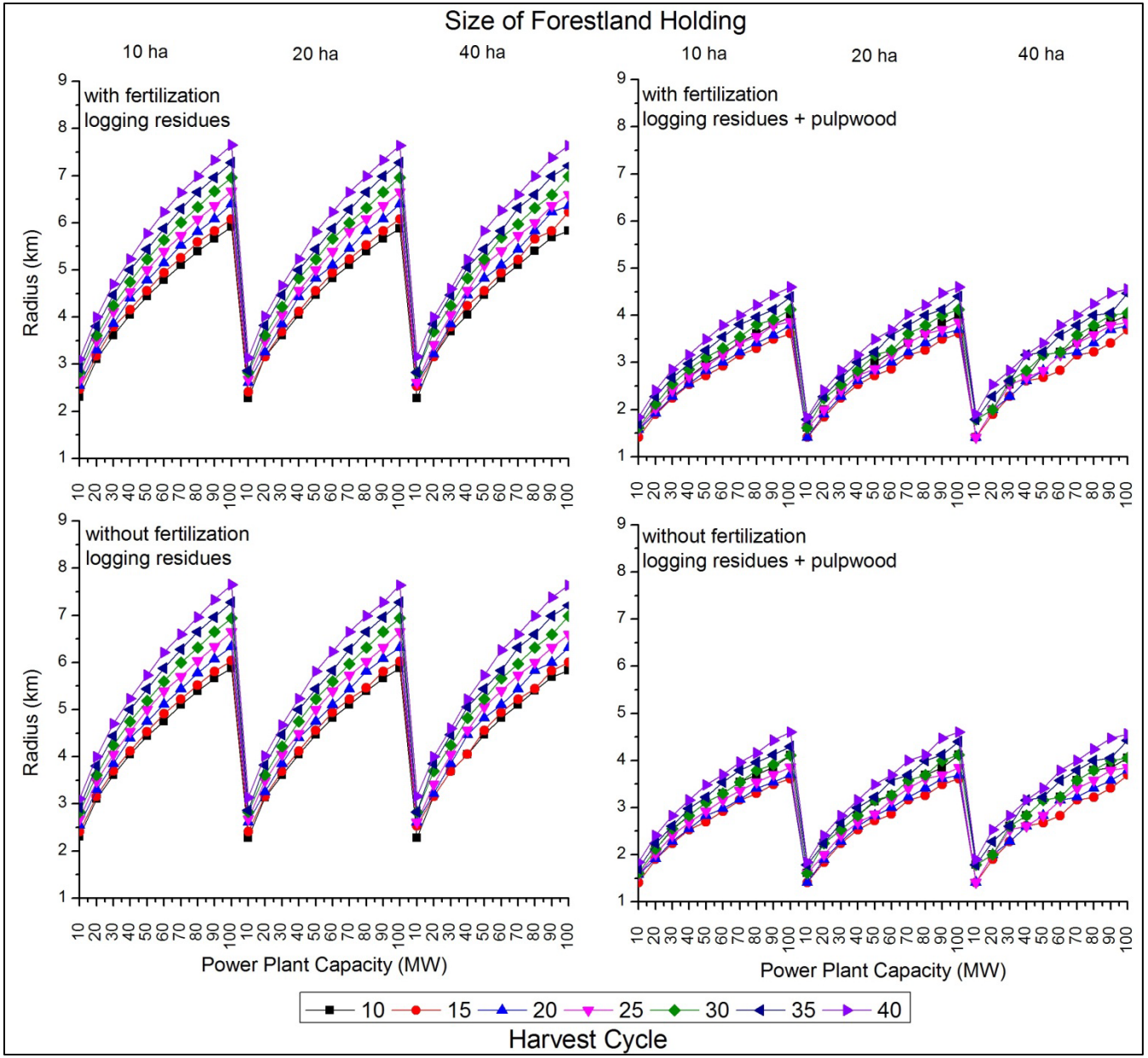


Wood and Wood Pellets

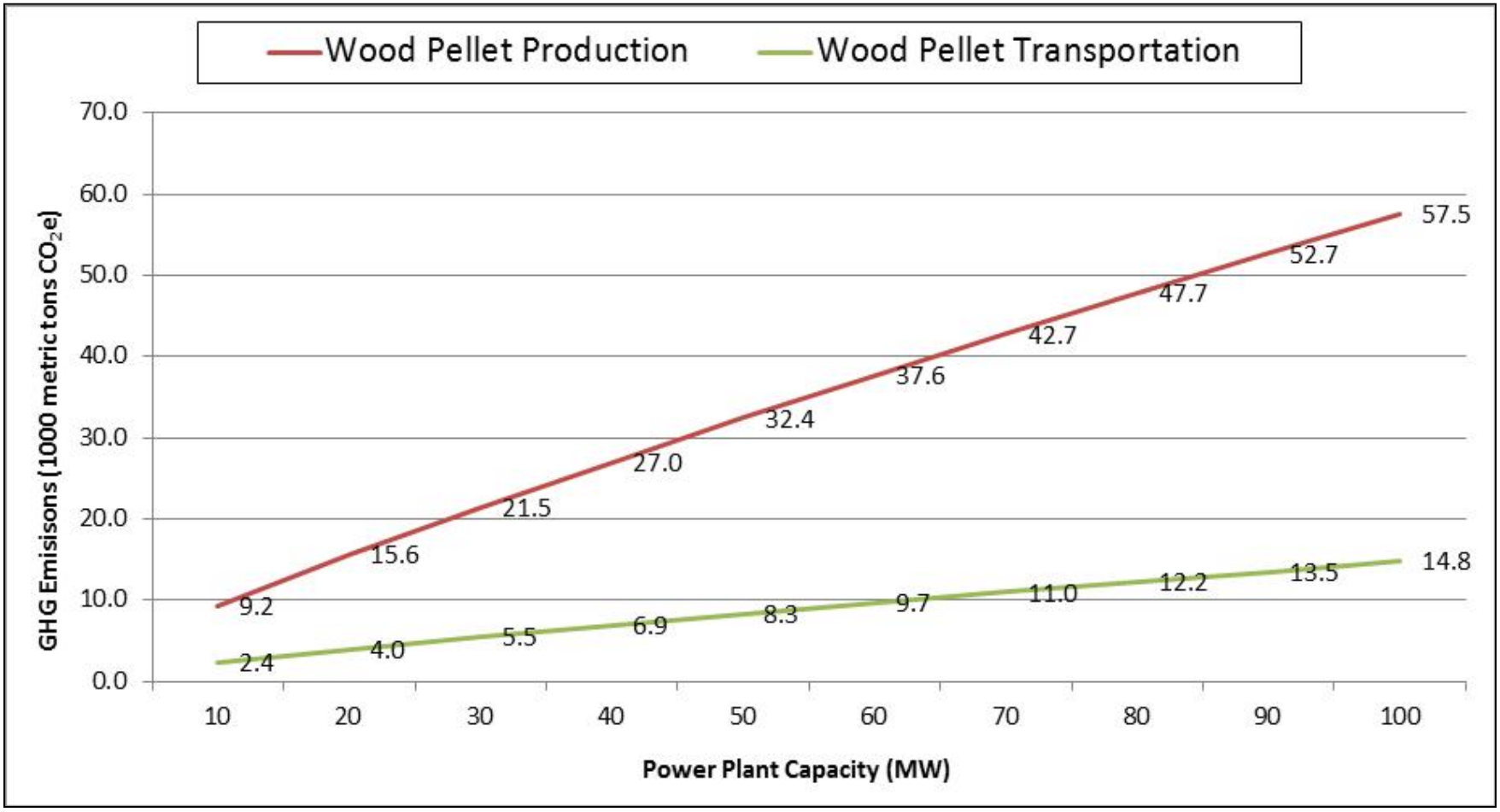
Procurement Radius



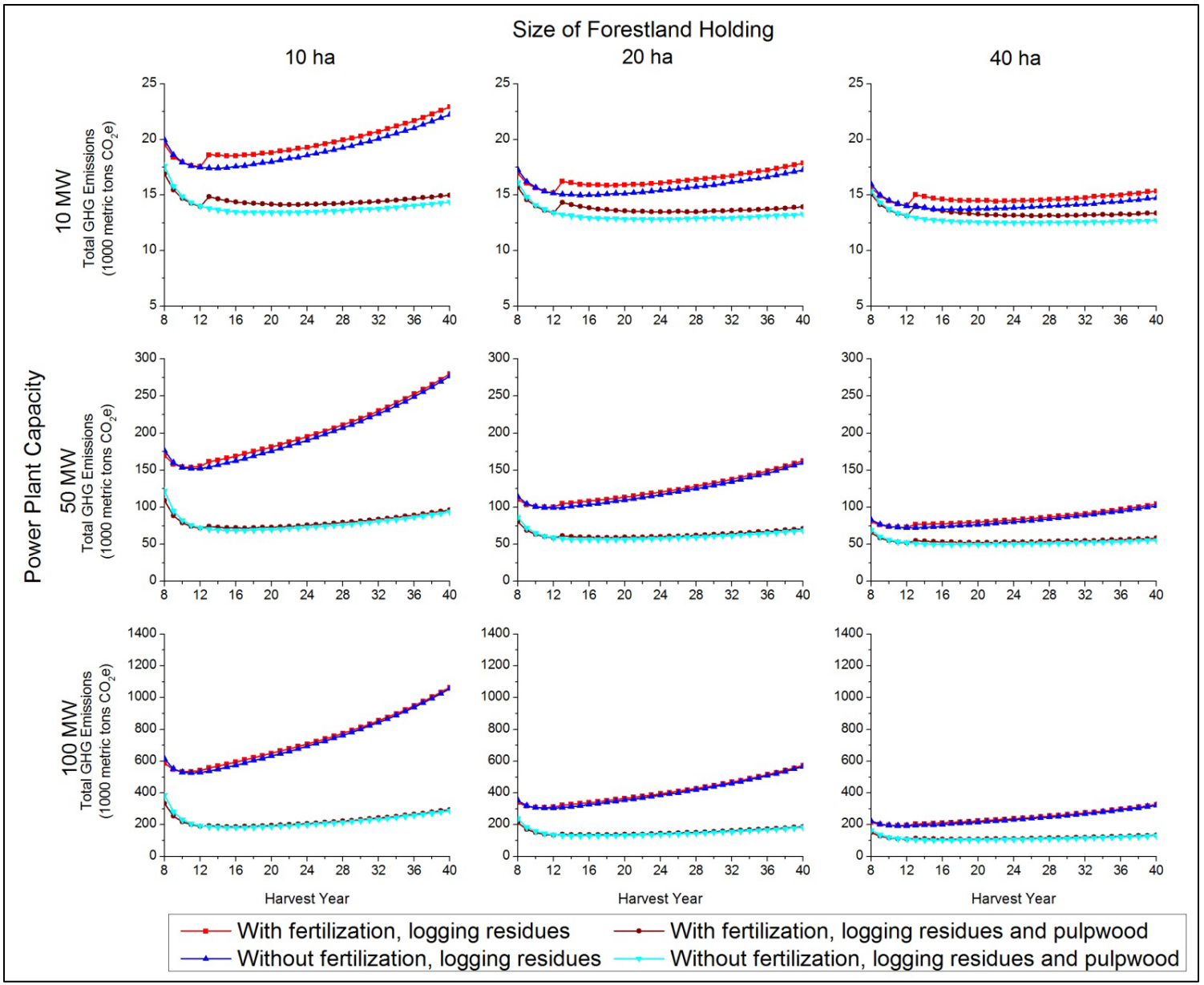
Procurement Radius



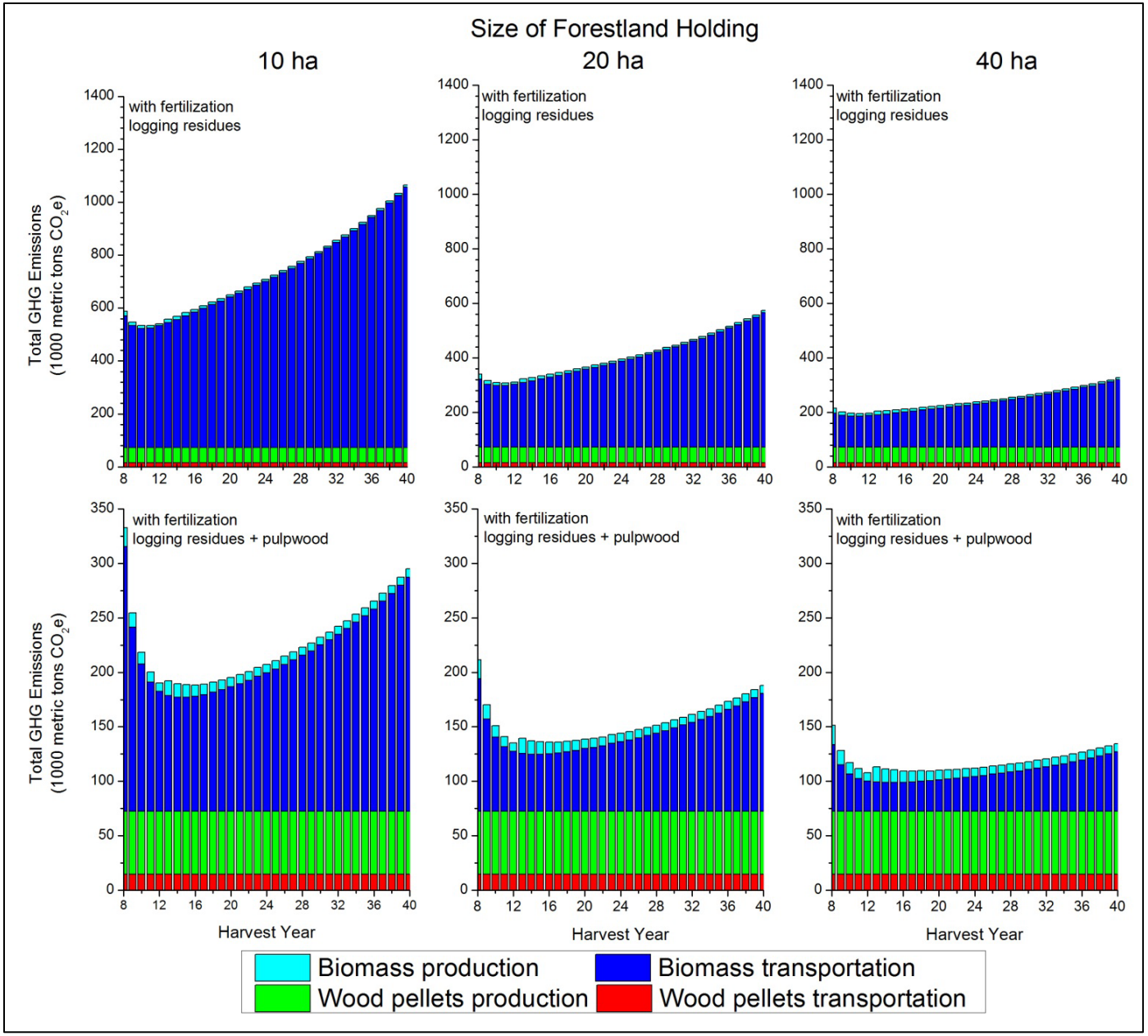
GHG Emissions



Total GHG Emissions

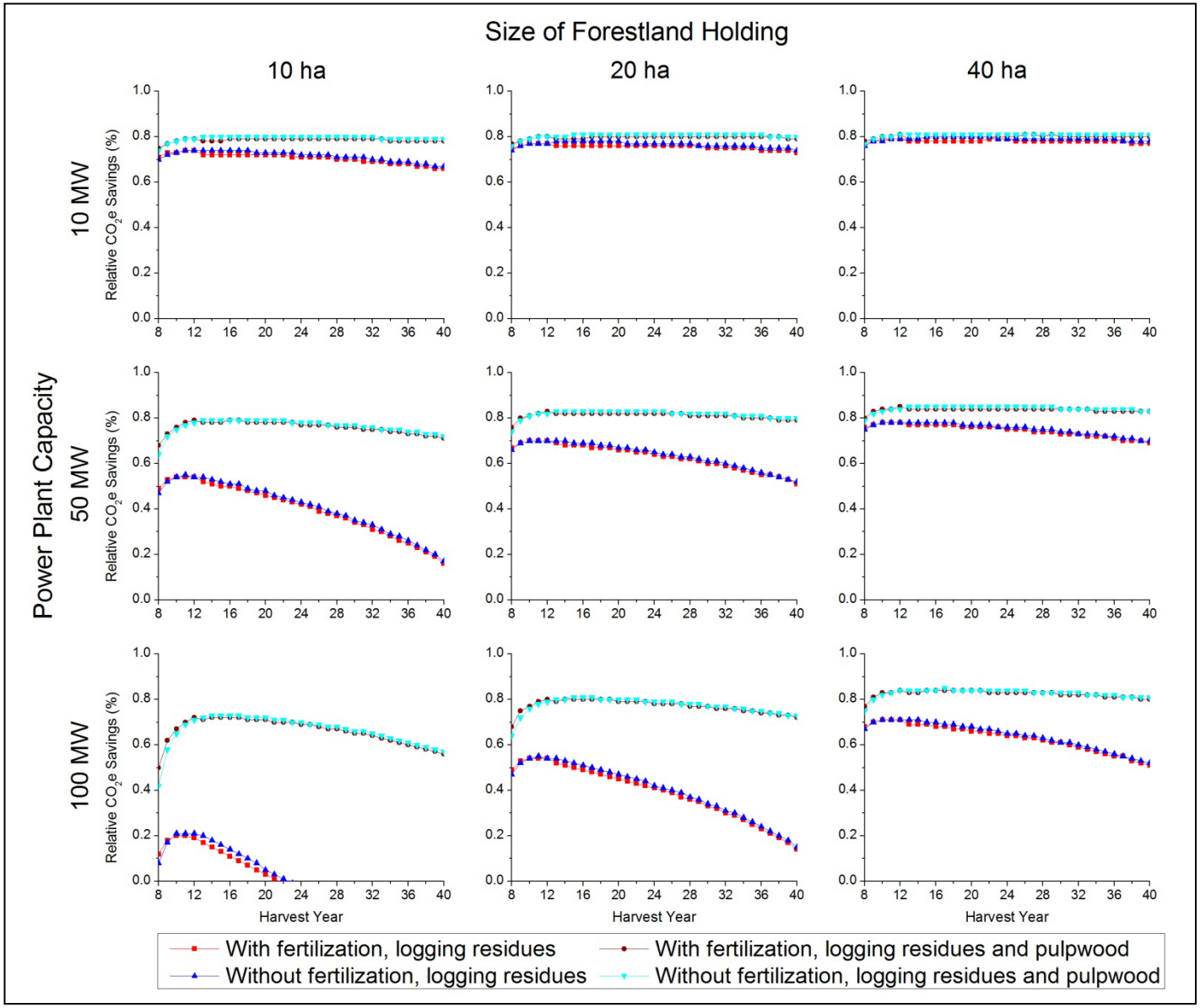


100 MW Power Plant



Discussions

Relative GHG Savings



Overall GHG Emissions

- Small capacity power plants (+)
- Large capacity power plants (+ or -)

Overall GHG Emissions

- Size of forestland holding (-)
- Feedstock types (-)
- Capacity of power plant (+)
- Harvest age (+)
- Fertilizer application (+)

Overall Sustainability

- Comprehensive planning
  - Sustainability indicators along with economic indicators
- Economic incentives for current forestland owners to avoid forestland parcelization
- Similar analysis for planned forest biomass-based cellulosic biofuels facilities

Conclusions

Limitations

- Carbon sequestration (above and below ground) is not considered
- Best estimates for relative reduction in GHG emissions
- Net economic and ecological impacts were not analyzed.

Policy Implication

- Precautionary principle
  - Burden of proof
- Need to be careful while promoting forest biomass-based bioenergy development.
- Implicit assumption that forest biomass based bioenergy development is always carbon beneficial needs to be tested on case-by-case basis.

Thanks!

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