Case studies of externality benefits of SRWCs in Florida: i) dendroremediation of reclaimed water, and ii) mined land reclamation

SRWCOWG October 12th, 2016

Matt Langholtz, ORNL
Model Explanation: Optimization of Coppice Plantations

Dual optimization:
1. Select optimum number of growth stages per cycle.
2. Select optimum length of each growth stage.
Model Explanation: Optimization of Coppice Plantations

Faustmann:

\[
LEV(t) = \frac{V(t) * e^{-r*t} - C}{1 - e^{-r*t}}
\]

\[
V'(t) = r * V(t) + r * LEV
\]
Model Explanation: Optimization of Coppice Plantations

Faustmann:

\[ LEV(t) = \frac{V(t) \cdot e^{-r \cdot t} - C}{1 - e^{-r \cdot t}} \]

\[ V'(t) = r \cdot V(t) + r \cdot LEV \]

Hartman (1976):

\[ LEV(t) = \frac{\int_0^t NTB(n) \cdot e^{-r \cdot t} \, dn + V(t) \cdot e^{-r \cdot t} - C}{1 - e^{-r \cdot t}} \]

\[ NTB(t) + V'(t) = r \cdot V(t) + r \cdot LEV \]
Model Explanation: Optimization of Coppice Plantations

Medema and Lyon (1985):

\[
LEV(t) = \sum_{s=1}^{n} \left[ V(t_s) \cdot e^{-r \sum_{j=1}^{s} t_j} \right] - C_s \cdot e^{-r \sum_{j=1}^{s} t_{j-1}}
\]

Smart and Burgess (2000):

\[
LEV(t) = \sum_{s=1}^{n} \left[ V(t_s) \cdot e^{-r \sum_{j=1}^{s} t_j} + NTB_s \cdot e^{-r \sum_{j=1}^{s} t_j} \right] - C_s \cdot e^{-r \sum_{j=1}^{s} t_{j-1}}
\]

\[
1 - e^{-r \sum_{j=1}^{n} t_j}
\]
Model Explanation: Optimization of Coppice Plantations

\[
W_{fu3}(t) := \left[ \begin{array}{c}
g(t)_1 \cdot e^{-i \cdot t_1} + \int_0^{t_1} \left( \frac{d}{dt_1} NTB_1(t_1) \right) \cdot e^{-i \cdot t_1} \ dt_1 - CE_{pr} \cdot NTB_1(t_1) \cdot e^{-i \cdot t_1} \end{array} \right] \left( C_p + C_w \right) \]

\[
+ \left[ \begin{array}{c}
g(t)_2 \cdot e^{-i \cdot (t_1+t_2)} + \int_0^{t_2} \left( \frac{d}{dt_2} NTB_2(t_2) \right) \cdot e^{-i \cdot t_2} \ dt_2 - i \cdot (t_1) - CE_{pr} \cdot NTB_2(t_2) \cdot e^{-i \cdot (t_1+t_2)} - \left[ C_w \cdot e^{-i \cdot t_1} \right] \end{array} \right] \]

\[
+ \left[ \begin{array}{c}
g(t)_3 \cdot e^{-i \cdot (t_1+t_2+t_3)} + \int_0^{t_3} \left( \frac{d}{dt_3} NTB_3(t_3) \right) \cdot e^{-i \cdot t_3} \ dt_3 - i \cdot (t_1+t_2) - CE_{pr} \cdot NTB_3(t_3) \cdot e^{-i \cdot (t_1+t_2+t_3)} - \left[ C_w \cdot e^{-i \cdot (t_1+t_2)} \right] \end{array} \right] \]

\[
1 - e^{-i \cdot (t_1+t_2+t_3)}
\]

\[
W_{03}(t) := \frac{\left[ \begin{array}{c}
g(t)_1 \cdot e^{-i \cdot t_1} - (C_p + C_w) \end{array} \right] + \left[ \begin{array}{c}
g(t)_2 \cdot e^{-i \cdot (t_1+t_2)} - \left[ C_w \cdot e^{-i \cdot (t_1+t_2)} \right] \end{array} \right] \left[ \begin{array}{c}
g(t)_3 \cdot e^{-i \cdot (t_1+t_2+t_3)} - \left[ C_w \cdot e^{-i \cdot (t_1+t_2)} \right] \end{array} \right] \left[ C_w \cdot e^{-i \cdot (t_1+t_2)} \right] \left[ C_w \cdot e^{-i \cdot (t_1+t_2)} \right]}{1 - e^{-i \cdot (t_1+t_2+t_3)}}
\]
Model Explanation: Optimization of Coppice Plantations

**Dual Optimization**

LEV per hectare: (Interest= 6%, wood value=20$ dry Mg\(^{-1}\), value of N removal= $1.00 kg\(^{-1}\)):

<table>
<thead>
<tr>
<th>Number of stages/cycle</th>
<th>Optimum stage length (years)</th>
<th>LEV ($/ha)</th>
<th>Marginal LEV ($/ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2.4</td>
<td>$ -1,072.00</td>
<td>-</td>
</tr>
<tr>
<td>1</td>
<td>2.3</td>
<td>$ +26.00</td>
<td>$ 1,098.00</td>
</tr>
<tr>
<td>2</td>
<td>2.3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>2.3</td>
<td>*</td>
<td>$ +72.00</td>
</tr>
<tr>
<td>2</td>
<td>2.3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>2.2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>2.4</td>
<td>$ -369.00</td>
<td>$ -44.00</td>
</tr>
<tr>
<td>2</td>
<td>2.3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>2.3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>2.0</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Background Scenario 1: Dendroremediation at Water Conserv II - Winter Garden

- 40% to RIBs
- 72 RIBs
- 1,500 Ha (3,725 acres)
- 14 million gal day$^{-1}$
- 7 ppm nitrate nitrogen;
- 1 ppm total phosphorus

Matt Langholtz, ORNL, Jan 21st, 2010
Background Scenario 1: Dendroremediation at Water Conserv II - Winter Garden

*E. grandis* at WCII:

- ~15 dry Mg ha$^{-1}$ yr$^{-1}$ @ 9,500 trees ha$^{-1}$
- Potential to mitigate nitrates and phosphates.
Background Scenario 1: Dendroremediation at Water Conserv II - Winter Garden

Objective:
Assess the impact of incentives for dendroremediation on profitability and management of SRWC culture irrigated with reclaimed water.

_E. grandis_ at WCII:
- ~15 dry Mg ha$^{-1}$ yr$^{-1}$ @ 9,500 trees ha$^{-1}$
- Potential to mitigate nitrates and phosphates.
Model Application: Dendroremediation

NTB functions:

Stock Benefit: \[ NTB_s^S = NTB_s(t) \]

Flow Benefit: \[ NTB_s^F = \left[ \int_0^t \left( \frac{d}{dt} \left( NTB_s(t) \right) \right) \ast e^{(-r \ast t)} \right] dt \]
Model Application: Water Conserv II Scenario

Model components: G&Y

G&Y Function:
• 2nd stage: 80%,
• 3rd state: 65%
• 4th stage 30%

Estimated Yield of Irrigated EG in FL

Yield (dry Mg ha⁻¹)

Time (years)

High Growth Function
Low Growth Function

Background 1 → Background 2 → Model Explanation → Model Application
Model Application: Water Conserv II Scenario

Model components: Nitrogen Accumulation:

<table>
<thead>
<tr>
<th>Tree Component</th>
<th>Nitrate Concentration</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stemwood</td>
<td>0.092%</td>
</tr>
<tr>
<td>Stem Bark</td>
<td>0.280%</td>
</tr>
<tr>
<td>Branches</td>
<td>0.272%</td>
</tr>
<tr>
<td>Leaves</td>
<td>1.390%</td>
</tr>
</tbody>
</table>

Nitrogen Accumulation in SRWC Plantation

G&Y Functions

Externalities
Model Application: Water Conserv II Scenario

Value of Nitrogen Removal

Valuation of N removal (City of Orlando Wastewater Treatment):
Total treatment costs: $0.88/1,000 gal
18ppm N removed=68g/1,000 gal
@ 5% of $0.88/1,000 = ~ $0.65 kg\(^{-1}\) N
@ 10% of $0.88/1,000 = ~ $1.29 kg\(^{-1}\) N

Increasing price of removing scarce N?
Decreasing willing to pay to remove additional N?

G&Y Functions

Externalities
Model Application: Water Conserv II Scenario
Assumptions:
Dendroremediation Incentives from $0-$3.50 kg⁻¹ N
Planting cost (with planting stock): $500 Ha⁻¹
Price of mulchwood: $20 dry Mg⁻¹
Irrigation Installment: $2,471 and $3,707 Ha⁻¹
Interest rate: 4 and 6%
Weed Control at coppice harvest: $120 Ha⁻¹
Annual Maintenance: $50 Ha⁻¹
Low and High Estimated Growth Functions
Dendroremediation Scenario: Results

• Every of $1 \text{ kg}^{-1}$ of N dendroremediation incentive increases LEV by $206$ to $246 \text{ Ha}^{-1}$ if treated as a stock benefit, or $246$ to $287 \text{ Ha}^{-1}$ if treated as a flow benefit.

• The LEV of the *Eucalyptus grandis* SRWC system is likely to be negative without compensation for N dendroremediation, depending largely on irrigation costs and productivity.

Background Scenario 2: Mined land reclamation and CO₂ mitigation using SRWCs

- 162,000 ha (400,000 ac) of phosphate-mined lands in Florida.
- 75% of the nation's and 25% of the world's phosphate supply (IMC Phosphates, 2002).
Background Scenario 2: CO$_2$ mitigation on CSAs using SRWCs

>40,000 ha (100,000 acres) of CSA lands in Central Florida.
Background Scenario 2: CO₂ mitigation on CSAs using SRWCs

Objective:
Assess the impact of incentives for CO₂ mitigation on profitability and management of SRWC culture on CSAs.
Model Application: CO$_2$ mitigation on CSAs using SRWCs

- SRWC-90, EG, EA; June 2001
- Area 22: EG, June 2002
- Area 23: EG, June 2001
- Demonstration area, EG, EA, and CW, April 2001

DBH and Ht data
Model Application: CO$_2$ mitigation on CSAs using SRWCs

![Graph showing DIB Growth Rates at Kent](image)

- **DBH and Ht data**
- **Profile data**
- **Yields**
- **G&Y Functions**
Model Application: CO₂ mitigation on CSAs using SRWCs

C Sequestration (mulch):

\[
NTB_s^M = \int_0^t \left( \frac{d}{dt} \left( C_{b_s} (t) \right) * e^{(-r*t)} \right) dt - \left[ \frac{C_{b_s} (t)}{5} * \left( \frac{1-e^{(-r*5)}}{r} \right) \right] * e^{(-r*t)}
\]

C Sequestration (biofuels):

\[
NTB_s^{BF} = \int_0^t \left( \frac{d}{dt} \left( C_{b_s} (t) \right) * e^{(-r*t)} \right) dt - \left[ (0.1*C_{b_s} (t)) \right] * e^{(-r*t)}
\]
Model Application: CO₂ mitigation on CSAs using SRWCs

Assumptions:

• Stumpage prices: $10, $20, and $30 dry Mg⁻¹.
• Site Preparation: $900 and $1,800 ha⁻¹.
• Planting cost: $600 and $1,200 ha⁻¹.
• Weed control: $0 and $200 ha⁻¹ stage⁻¹.
• Growth and Yield: Low (EA 3) and High (EA 4).
• Scenarios: No NTB, NTB (Mulch), and NTB (Biofuels)
• C Price: $0, $5, and $10 Mg⁻¹ C
Model Application: Water Conserv II Scenario

LEVs ($/ha) as a function of Dendroremediation Incentive

- $\Delta$ - I=4%, G=H, B=F, Irr=$2,471
- $\Delta$ - I=4%, G=L, B=F, Irr=$2,471
- $\Delta$ - I=6%, G=H, B=F, Irr=$2,471
- $\Delta$ - I=6%, G=L, B=F, Irr=$2,471
Model Application: Water Conserv II Scenario
LEVs ($/ha) as a function of Dendroremediation Incentive

![Graph showing LEVs ($/ha) as a function of Dendroremediation Incentive with different scenarios and rates.](image)
Model Application: Water Conserv II Scenario

Condensed Prediction Equation

\[
LEV(I, g, Y, \nu, N) = \left( \beta_0 * e^{-\beta_1 I} + g * \beta_2 * e^{-\beta_3 I} - Y \right) + \\
\left( \beta_4 * e^{-\beta_5 I} + \beta_6 * \nu + g * \beta_7 * e^{\beta_8 I} \right) * N + \varepsilon
\]

<table>
<thead>
<tr>
<th>Variable</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>$I$</td>
<td>Real interest rate.</td>
</tr>
<tr>
<td>$g$</td>
<td>Growth model, $-1 \leq g \leq 1$, where $-1$ and $1$ represent the low and high growth, respectively, as represented in Figure 1.</td>
</tr>
<tr>
<td>$Y$</td>
<td>Price of irrigation establishment, $$/ha$^{-1}$</td>
</tr>
<tr>
<td>$\nu$</td>
<td>$0=stock$ benefit calculation, $1=flow$ benefit calculation</td>
</tr>
<tr>
<td>$N$</td>
<td>Value of N dendroremediation benefit, $$/kg$^{-1}$.</td>
</tr>
</tbody>
</table>
Model Application: Water Conserv II Scenario

\[
\frac{d}{dt} v(t) \quad \frac{v(t)}{t}
\]

Yield (dry Mg)

\[V_{\text{max}} = 2.9\]
Model Application: CO$_2$ mitigation on CSAs using SRWCs
Model Application: CO$_2$ mitigation on CSAs using SRWCs

![DIB Growth, SRWC-90 graph](image)

- **DBH and Ht data**
- **Profile data**
- **Yields**

Legend:
- EA 3 Average
- EA 4 Average
- Predicted EA3
- Predicted EA4
Model Application: CO₂ mitigation on CSAs using SRWCs

WCII IB and Lakeland OB Yield Comparison

Yield (dry Mg ha⁻¹) vs. time (years)

- WCII Low Estimate
- WCII High Estimate
- Lakeland EA 3
- Lakeland EA 4

Yields

DBH and Ht data
Profile data

G&Y Functions
Model Application: CO$_2$ mitigation on CSAs using SRWCs

<table>
<thead>
<tr>
<th>Product</th>
<th>$/kWh</th>
<th>$/green ton</th>
<th>$/dry Mg</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mulch (low)</td>
<td></td>
<td>$8</td>
<td>$18</td>
</tr>
<tr>
<td>Mulch (high)</td>
<td></td>
<td>$16</td>
<td>$35</td>
</tr>
<tr>
<td>Biofuels (delivered, coal equivalent)</td>
<td></td>
<td>$15</td>
<td>$34</td>
</tr>
<tr>
<td>Biofuels (stumpage, coal equivalent)</td>
<td></td>
<td>$0</td>
<td>$0</td>
</tr>
<tr>
<td>Renewable Energy Marketing (delivered)</td>
<td>2.5¢</td>
<td>$18</td>
<td>$41</td>
</tr>
<tr>
<td>REPI (delivered)</td>
<td>1.76¢</td>
<td>$13</td>
<td>$29</td>
</tr>
<tr>
<td>Section 45 (delivered)</td>
<td>2.75¢</td>
<td>$20</td>
<td>$45</td>
</tr>
<tr>
<td>High Biofuels (delivered, renewable+Sec 45)</td>
<td></td>
<td>$39</td>
<td>$85</td>
</tr>
</tbody>
</table>

Section 45 (delivered, renewable+Sec 45)

|$/dry Mg, Stumpage$

- Mulch: $10 and $20
- Biofuels: $10, $20, $30
Model Application: CO$_2$ mitigation on CSAs using SRWCs

Model Application:

- DBH and Ht data
- Profile data
- Yields
- G&Y Functions
- Optimization Model
- Externalities

LEV as a function of Biomass Price

LEV ($ per ha)

Stumpage Price ($ per dry Mg)

$20,000

$15,000

$10,000

$5,000

$0

-$5,000

$10

$20

$30

$5,000

$10,000

$15,000

$20,000

Profitability, Optimum harvest scheduling

Model Application
Modeled SOC C Sequestration

\[ \text{SOC}_\text{max} = 45 \]

\[ \text{SOC}(\text{SOC}_\text{max}) = 341 \]

\[ \frac{\text{SOC}(\text{SOC}_\text{max})}{\text{SOC}_\text{max}} = 7.5 \]

Above ground (high growth)

\[ C_m(3.2) = 47 \]

\[ \frac{C_m(3.2)}{3.2} = 14.8 \]

Above ground (low growth)

\[ C_m(2.9) = 23 \]

\[ \frac{C_m(2.9)}{2.9} = 7.8 \]

SOC Accumulation (Mg/ha)

Time (years)

SOC(t)

SOC\(_{\text{max}}\)

SOC\(_{(\text{SOC}_{\text{max}})}\)

SOC\(_{\text{max}}\)

SOC\(_{(\text{SOC}_{\text{max}})}\)
Model Application: CO$_2$ mitigation on CSAs using SRWCs

Interest 4%, Site prep $1,800$ ha$^{-1}$, Planting $1,200$ ha$^{-1}$, C $5$ Mg$^{-1}$

<table>
<thead>
<tr>
<th>NTB</th>
<th>Growth</th>
<th>$10$/dry Mg</th>
<th>$20$/dry Mg</th>
<th>$30$/dry Mg</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>LEV ($/ha$)</td>
<td>Harvest age (years)</td>
<td>LEV ($/ha$)</td>
</tr>
<tr>
<td>None</td>
<td>Low</td>
<td>-1,967</td>
<td>3.1, 3.1, 3.2, 3.3, 3.4</td>
<td>674</td>
</tr>
<tr>
<td>C(M)</td>
<td>Low</td>
<td>-1,883</td>
<td>3.1, 3.1, 3.2, 3.2, 3.3</td>
<td>771</td>
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<tr>
<td>C(B)</td>
<td>Low</td>
<td>-1,424</td>
<td>3.0, 3.1, 3.1, 3.1, 2.9</td>
<td>1,320</td>
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<tr>
<td>None</td>
<td>High</td>
<td>619</td>
<td>3.4, 3.4, 3.3, 3.0</td>
<td>6,507</td>
</tr>
<tr>
<td>C(M)</td>
<td>High</td>
<td>810</td>
<td>3.4, 3.4, 3.3, 3.0</td>
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<tr>
<td>C(B)</td>
<td>High</td>
<td>1,832</td>
<td>3.4, 3.4, 3.3, 2.9</td>
<td>7,869</td>
</tr>
</tbody>
</table>

* Not including below ground C sequestration.
## Response to Changes in C Price

Stumpage price $20 dry Mg\(^{-1}\), Interest 4%, Site prep $1,800 ha\(^{-1}\), Planting $1,200 ha\(^{-1}\)

### Mulch scenario:

<table>
<thead>
<tr>
<th>$/Mg C</th>
<th>LEV ($/ha)</th>
<th>Optimum Stage Lengths (years)</th>
<th>Marginal Benefit (LEV increment per $ Incentive)</th>
<th>Below Ground ($/ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>6,507</td>
<td>3.2, 3.1, 2.9</td>
<td>n/a</td>
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<tr>
<td>5</td>
<td>6,715</td>
<td>3.2, 3.1, 2.9</td>
<td>42</td>
<td>1,163</td>
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<tr>
<td>15</td>
<td>7,131</td>
<td>3.3, 3.1, 2.9</td>
<td>42</td>
<td>3,492</td>
</tr>
<tr>
<td>25</td>
<td>7,548</td>
<td>3.3, 3.2, 2.9</td>
<td>42</td>
<td>5,819</td>
</tr>
<tr>
<td>35</td>
<td>7,965</td>
<td>3.3, 3.2, 2.9</td>
<td>42</td>
<td>8,097</td>
</tr>
</tbody>
</table>

### Biofuels scenario:

<table>
<thead>
<tr>
<th>$/Mg C</th>
<th>LEV ($/ha)</th>
<th>Optimum Stage Lengths (years)</th>
<th>Marginal Benefit (LEV increment per $ Incentive)</th>
<th>Below Ground ($/ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>6,507</td>
<td>3.2, 3.1, 2.9</td>
<td>n/a</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>7,869</td>
<td>3.2, 3.1, 2.9</td>
<td>272</td>
<td>1,163</td>
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<tr>
<td>15</td>
<td>10,598</td>
<td>3.2, 3.1, 2.8</td>
<td>273</td>
<td>3,492</td>
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<td>25</td>
<td>13,505</td>
<td>3.1, 3.0</td>
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<td>35</td>
<td>16,422</td>
<td>3.1, 3.0</td>
<td>292</td>
<td>8,097</td>
</tr>
</tbody>
</table>
Sensitivity Analysis:

• CO₂ Mitigation: 1$ increase Mg⁻¹ C incentive increases LEV by $17-$42 (mulch) or $109-$292 (biofuels), +~$249 for below ground sequestration ($ ha⁻¹).

• Stumpage Price: 1$ increase dry Mg⁻¹ $284-$629 ha⁻¹.

• Growth and Yield: High growth increases LEV by $2,586-$9,971 ha⁻¹.

• Interest rate: 1% increase decreases LEV by $142-$2,581 ha⁻¹.

• Planting Cost: $100 cost increase decreases LEV by $289-$467 ha⁻¹.

• Decreased harvest costs= ~increased stumpage value.
Results: SRWC on CSAs

• SRWC production likely profitable (LEV>0) assuming stumpage value $20 dry Mg$^{-1}$.

• LEVs ranging from $762 to $6,507 ha$^{-1}$ assuming discount rates of 10% and 4%, respectively.

Results: CO$_2$ mitigation on CSAs using SRWCs

• CO$_2$ mitigation incentives of $5 \text{ Mg}^{-1} \text{ C}$ increase LEVs $84$-$191 \text{ ha}^{-1}$ for mulch and $543$-$1,459 \text{ ha}^{-1}$ for biofuels.

• At C prices up to $15 \text{ Mg}^{-1} \text{ C}$, influence of CO$_2$ mitigation incentives on optimum coppice stage lengths is not operationally significant.

Where do we go?

• Related interests: BETO gulf hypoxia workshop
• CBW water quality-bridge the gap between WTP and WTA?
• USDA environmental markets
• Local governments?
### SRWC Decision Support System:

#### Land Expectation Value (LEV), Equal Annual Equivalent (EAE), Internal Rate of Return (IRR), and Net Present Value (NPV) Calculator

<table>
<thead>
<tr>
<th>INPUTS</th>
<th></th>
<th></th>
<th></th>
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</thead>
<tbody>
<tr>
<td>Stumpage Price, Incentives, Capital Cost</td>
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<td></td>
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</tr>
<tr>
<td>Stumpage price ($ green ton⁻¹)</td>
<td></td>
<td></td>
<td>$10</td>
</tr>
<tr>
<td>Renewable Energy Portfolio Incentive ($ green ton⁻¹)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Other Incentives ($ green ton⁻¹)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total stumpage value ($ green ton⁻¹)</td>
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<td></td>
<td>$10</td>
</tr>
<tr>
<td>Capital cost (annual interest rate)</td>
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<td>5.0%</td>
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</tbody>
</table>

| Start-up Costs | | | |
| Herbicide ($ acre⁻¹) | | | $200 |
| Site Prep ($ acre⁻¹) | | | $50 |
| Disk ($ acre⁻¹) | | | $90 |
| Bed ($ acre⁻¹) | | | $200 |
| Total: | | | $540 |

| Costs at the Beginning of Each Rotation | | | |
| Fertilize ($ acre⁻¹) | | | $40 |
| Progress price per tree | | | $0.11 |
| Trees per acre (7,200-3,400) | | | $3,000 |
| Cost of Trees ($ acre⁻¹) | | | $3374 |
| Planting cost ($ acre⁻¹) | | | $150 |
| Total | | | $564 |

| Costs at the Beginning of Each Coppice | | | |
| Weed control ($ acre⁻¹) | | | $40 |

#### Annual Costs

| | | |
| Annual maintenance/administration ($ acre⁻¹) | | $10 |

### General Parameters

| | | |
| Inside bark or total above-ground biomass | Total above-ground biomass | 1.7 |
| Expansion factor for branches and leaves | | 4.0 |
| Number of coppices per rotation | | 4 |
| Age of first harvest | | 5.0 |
| Harvest age of first coppice | | 3.0 |
| Harvest age of second coppice | | 3.0 |
| Harvest age of third coppice | | 3.0 |
| Total Rotation Length | | 12.0 |

| | | |
| Initial harvest yield (as % of first harvest) | | 100% |
| First coppice yield (as % of first harvest) | | 80% |
| Second coppice yield (as % of first harvest) | | 70% |
| Third harvest yield (as % of first harvest) | | 60% |

#### Estimated Yield within a Rotation:

| | Initial | 1st Cop. | 2nd Cop. | 3rd Cop. |
| Green tons per acre | | | | |

#### Yields (green tons acre⁻¹) by harvest age within a rotation

| | |
| Initial harvest at 3 years of age | 65.1 |
| First coppice at 3 years of age | 68.1 |
| Second coppice at 3 years of age | 69.6 |
| Third coppice at 3 years of age | 81.1 |

Figure 1. The SRWC Decision Support System spreadsheet.
Questions?

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