IS RISK DIVERSIFICATION A JUSTIFICATION FOR PROVIDING MULTIPLE ECOSYSTEM SERVICES?

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PES and private capital investment

- Payments for ecosystem services (PES) are emerging
- Suppliers in ecosystem service markets are the landowners
- Buyers in ecosystem service markets:
  1. those who are currently enjoying those services for free
  2. private investors
- Why we should pay attention to the private investors:
  - Individual and institutional investors have long viewed forestry-related investments as a way of diversifying risk and hedging against inflation
  - $228 billion is currently being managed in impact investing assets and 13 percent ($29.6 billion) is directed at water, forestry, and conservation
  - A potential private alternative to USDA programs (e.g., CRP, resource sales, etc.)
- Little analysis of the factors that drive these investments
A finance analogy

Asset managers separate the functions of analysts and portfolio managers

• Analyst
  • Values individual ecosystem assets using nonmarket valuation
  • Value is created from the correct valuation of the asset (direct/indirect use values, existence value, option value, altruistic value, bequest value, etc.)
  • Under provision of ecosystem service due to undervaluation of that asset
  • Invest if expected benefit (asset valuation) exceeds the cost (share price)

• Portfolio manager
  • Value created from individual assets AND the mix of assets in a portfolio
  • Some assets have a risk diversification value (in addition to traditional notion of value)
  • May not invest if expected benefit (asset valuation) exceeds the cost (share price)

Private investors more inline with portfolio manager’s perspective
Research questions

1. Which ecosystem services are likely to attract private investment?

2. How does the expansion of nonmarket valuation redirect private investment?

3. What is the risk diversification value of ecosystem services?
Approach: Modern portfolio theory

• Optimal mix of assets in a portfolio depends on the expected return and risk of each individual asset and the relationship between the variation in returns of the assets.

• Generates an efficient frontier that reflects the price of a risk reduction.

• Previous research has treated species as assets to value biodiversity or land as assets to guide land purchasing decisions.
Approach: Modern portfolio theory

- Ecosystem services provide an unpredictable return
- REITs own land for the purpose of providing ecosystem services
  - 4 Timberland REITs with a total market cap of nearly $27 billion
  - Sell conservation easements to incorporate other ecosystem services
- Allows investment in land managed for a particular ecosystem service through the purchase of REIT stock rather than purchasing land
- Investor chooses the proportion of a budget allocated to different ecosystem services to maximize the expected return from that budget
Risk-free return: 2%

Capital market line

Efficient frontier

Tangency portfolio

Timber

Water yield

Grazing
Risk diversification value of an ecosystem service

Return (%)

Risk (%)

Return forfeited to reduce risk

Risk-free return: 2%
Hypothetical example

- Public lands act as REIT
- Calculate avg. ROI/acre
- Private investors buy stock in public land REIT
Our notion of risk

• Unexpected fire and insect outbreaks temporarily lower returns
• Fire/insects make it risky to have assets co-located
• Assume that each year 0.6% (1 million acres) of REIT landholdings are randomly burned
• Risky ecosystem services are those that tend to be collocated with other ecosystem services
Ecosystem services as risky assets

- The landscape is composed of \( K \) spatial units indexed by \( k \)
- Unknown economic return from investing in ecosystem service \( i \) is
  \[
  R_i = \sum_{k=1}^{K} v_{ik}(q_{ik})q_{ik} - DL_i
  \]
  where
  - \( q_{ik} \) is the physical measure of the ecosystem service \( i \) in spatial unit \( k \) (e.g., board feet of timber, animal unit months, acre feet of water)
  - \( v_{ik} \) is the value per physical unit (e.g., stumpage price, grazing fee, water price)
  - \( D \) is the number of acres impacted by fire and insect outbreak
  - \( L_i \) is a normally distributed random variable representing the per acre loss to ecosystem service \( i \) with mean \( \mu_i = \sum_{k=1}^{K} v_{ik}(q_{ik})q_{ik} / K \) and standard deviation
  \[
  s_i = \sqrt{\frac{1}{K} \sum_{k=1}^{K} (v_{ik}(q_{ik})q_{ik} - \mu_i)^2}
  \]
### Mean return, standard deviation of return, and covariance matrix

<table>
<thead>
<tr>
<th></th>
<th>Timber</th>
<th>Grazing</th>
<th>Water yield</th>
<th>Water filtration</th>
<th>Carbon sequestration</th>
</tr>
</thead>
<tbody>
<tr>
<td>Timber</td>
<td>0.0000</td>
<td>-0.0000</td>
<td>0.0000</td>
<td>0.0000</td>
<td>0.0001</td>
</tr>
<tr>
<td>Grazing</td>
<td>-0.0000</td>
<td>0.0403</td>
<td>-0.0000</td>
<td>-0.0062</td>
<td>-0.0091</td>
</tr>
<tr>
<td>Water yield</td>
<td>0.0000</td>
<td>-0.0000</td>
<td>0.0000</td>
<td>-0.0001</td>
<td>0.0001</td>
</tr>
<tr>
<td>Water filtration</td>
<td>0.0000</td>
<td>-0.0062</td>
<td>-0.0001</td>
<td>0.5897</td>
<td>0.0193</td>
</tr>
<tr>
<td>Carbon sequestration</td>
<td>0.0001</td>
<td>-0.0091</td>
<td>0.0001</td>
<td>0.0193</td>
<td>0.0437</td>
</tr>
<tr>
<td>Mean annual return (%)</td>
<td>0.08</td>
<td>10.58</td>
<td>0.56</td>
<td>32.27</td>
<td>50.81</td>
</tr>
<tr>
<td>Standard deviation (%)</td>
<td>0.01</td>
<td>2.01</td>
<td>0.01</td>
<td>7.68</td>
<td>2.09</td>
</tr>
</tbody>
</table>
Which ecosystem services are likely to attract private investment?

<table>
<thead>
<tr>
<th>Service</th>
<th>Mean annual return (%)</th>
<th>Portfolio weights</th>
</tr>
</thead>
<tbody>
<tr>
<td>Timber</td>
<td>0.08</td>
<td>0.00</td>
</tr>
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<td>0.00</td>
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<tr>
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<td>0.01</td>
</tr>
<tr>
<td>Carbon sequestration</td>
<td>50.81</td>
<td>0.70</td>
</tr>
</tbody>
</table>
How does the expansion of nonmarket valuation redirect private investment?

Tangency portfolio when regulating ecosystem services are valued

<table>
<thead>
<tr>
<th>Ecosystem goods only</th>
<th>Timber</th>
<th>Grazing</th>
<th>Water yield</th>
<th>Water filtration</th>
<th>Carbon sequestration</th>
<th>Expected return</th>
<th>Standard deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0.56</td>
<td>0.00</td>
<td>0.44</td>
<td>NA</td>
<td>NA</td>
<td>0.026</td>
<td>0.001</td>
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<tr>
<td>Ecosystem goods and water quality</td>
<td>0.00</td>
<td>0.82</td>
<td>0.00</td>
<td>0.18</td>
<td>NA</td>
<td>0.318</td>
<td>0.039</td>
</tr>
<tr>
<td>Ecosystem goods and carbon sequestration</td>
<td>0.00</td>
<td>0.29</td>
<td>0.00</td>
<td>NA</td>
<td>0.71</td>
<td>0.601</td>
<td>0.019</td>
</tr>
<tr>
<td>All ecosystem goods and services</td>
<td>0.00</td>
<td>0.29</td>
<td>0.00</td>
<td>0.01</td>
<td>0.70</td>
<td>0.40</td>
<td>0.013</td>
</tr>
</tbody>
</table>
What is the risk diversification value of ecosystem services?

\[ \text{Div}_i = f(R_i, \sigma_i, R_j, \sigma_j, COV_{ij}, r) \quad j = \text{all other ES} \]

<table>
<thead>
<tr>
<th></th>
<th>Mean annual return (%)</th>
<th>Portfolio weights</th>
<th>Diversification value (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Timber</td>
<td>0.08</td>
<td>0.00</td>
<td>0.0</td>
</tr>
<tr>
<td>Grazing</td>
<td>10.58</td>
<td>0.29</td>
<td>14.3</td>
</tr>
<tr>
<td>Water yield</td>
<td>0.56</td>
<td>0.00</td>
<td>0.0</td>
</tr>
<tr>
<td>Water filtration</td>
<td>32.27</td>
<td>0.01</td>
<td>11.2</td>
</tr>
<tr>
<td>Carbon sequestration</td>
<td>50.81</td>
<td>0.70</td>
<td>32.2</td>
</tr>
</tbody>
</table>
Conclusions

1. Private investments not necessarily attracted to ecosystem services with the highest return

2. Expanding valuation to regulating services either increases the return or decreases the risk of private ecosystem portfolios
   • Shifts capital from traditional provisioning services (timber, water yield) to regulating services like carbon sequestration

3. Diversification value can be significant for ecosystem services in the portfolio
   • Diversification value can be larger than the expected return
THANK YOU.
QUESTIONS?

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Future work

• Utility theoretic approach to valuing diversification
• Account for other temporal sources of risk
• Can we characterize the type of portfolio (e.g., large cap stocks, small cap stocks) that includes ecosystem services?
• CVaR to allow for skewness and kurtosis
MPT for ecosystem services

- The expected return on a portfolio of ecosystem services is \( R_p = \sum_i \omega_i R_i \) where \( R_i \) is the random return of ecosystem service \( I \)
- Variance of the portfolio of ecosystem services (a measure of the risk of a portfolio) is the sum of all individual variances plus all covariances

\[
\sigma_p^2 = \sum_i (\omega_i \sigma_i)^2 + \sum_i \sum_j (\omega_i \omega_j \text{COV}_{ij}) = \sum_i (\omega_i \sigma_i)^2 + \sum_i \sum_j (\omega_i \omega_j \sigma_i \sigma_j \rho_{ij})
\]

where
- \( \text{COV}_{ij} \) is the covariance of ecosystem services \( i \) and \( j \)
- \( \sigma_i \) is the standard deviation of the return on ecosystem service \( I \)
- \( \rho_{ij} \) is the correlation between ecosystem services \( i \) and \( j \)
How does the expansion of nonmarket valuation redirect private investment?

Ecosystem goods and carbon sequestration

Ecosystem goods and water filtration

Ecosystem goods only