Bigger is Better:
Optimizing Forest Code Compliance to Sustain Brazilian Agriculture, Biodiversity & Ecosystem Services at a Landscape-Scale

The Nature Conservancy (TNC)
Development by Design
Christina M. Kennedy
Daniela A. Miteva
Kei Sochi
James R. Oakleaf
Joseph Kiesecker

TNC - Atlantic Forest
Central Savannas
Leandro Baumgarten
Marcelo Matsumoto

Natural Capital Project/UMN
Institute on the Environment
Peter L. Hawthorne
Steve Polasky
Perrine Hamel

The Dow Chemical Company
Elizabeth M. Uhlhorn
Socio-Environmental Context

- Cerrado: Global biodiversity hotspot, with less than 50% natural habitat & < 2% protected (Klink & Machado 2005)
- Land use: cattle ranching and increasingly sugarcane production (Lapola et al. 2010)
- Nature conservation on agriculture (private) lands is vital and regulated by the Brazilian Forest Code (FC) (Soares-Filho et al. 2014)
- Brazil pilot: Guide business decisions about land use to meet the FC and to optimize agricultural production and benefits of habitat restoration, biodiversity & ecosystem services
Brazilian Forest Code

Legal Reserve 80%

Legal Reserve 20%

Rural Property

LEGAL AMAZON

NON LEGAL AMAZON

Agriculture

Brazil pilot

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Brazilian Forest Code

LEGAL AMAZON

NON LEGAL AMAZON

Rural Property

River

Agriculture

Permanent Preservation Area (PPA)

Brazil pilot
Forest Code Compliance at Different Spatial Scales

Property (farm)-level
Forest Code Compliance at Different Spatial Scales

Landscape (watershed)-level
Spatial Scale to Minimize Business Costs & Maximize Nature Benefits

Landscape-level Compliance

Land Use Land Cover Class:
- Cerrado (Broad leaf forest)
- Cerrado (Shrubland)
- Semideciduous Forest
- Wetland
- Pasture
- Sugarcane
- Other Cultivate
- Development
- Water

Minas Gerais State

Goiás State

Brazil
Spatial Scale to Minimize Business Costs & Maximize Nature Benefits

Landscape-level Compliance

Property-level Compliance
Economic & Environmental Modeling

**Agriculture**
Cattle ranching
Sugar cane
- Economic return ($)

**Forest Code**
- Amount of habitat required (LRs + PPAs)
- Cost of Forest Code compliance ($)

**Biodiversity**
- # of Birds & Mammals in landscape

**Terrestrial Surface Water Quality & Carbon Sequestration**
- Nutrients & sediments in waterways
- Carbon sequestration from habitats
1st Optimization Approach: Minimize Cost

- **Agriculture**
  - Cattle ranching
  - Sugar cane
  - Economic return (\$)

- **Forest Code**
  - Amount of habitat required (LRs + PPAs)
  - Cost of Forest Code compliance (\$

- **Biodiversity**
  - # of Birds & Mammals in landscape

- **Terrestrial Surface Water Quality & Carbon Sequestration**
  - Nutrients & sediments in waterways
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Landscape-level Planning: Better for Business & Nature

Property-level

- Profitable land set-aside for FC compliance
- Additional 30-69 farms needed to meet production
- More habitat required for compliance: 11,500 (±2600) ha
- Habitat is more fragmented

Landscape-level

- Cost savings: USD $19-$35 million
- Reduced transportation, leasing, and restoration costs
- Supports up to 74 more species
- Stores 151,000 additional tons carbon (with restoration): Valued at $1-17.5 million
- Similar water quality
2nd Optimization Approach: Efficiency Frontiers

- **Agriculture**: Cattle ranching, Sugar cane
  - Economic return ($)

- **Forest Code**:
  - Amount of habitat required (LRs + PPAs)
  - Cost of Forest Code compliance ($)

- **Biodiversity**:
  - # of Birds & Mammals in landscape

- **Terrestrial Surface Water Quality & Carbon Sequestration**:
  - Nutrients & sediments in waterways
  - Carbon sequestration from habitats
2nd Optimization Approach: Efficiency Frontiers

**Agriculture**
- Cattle ranching
- Sugar cane

- Economic return ($)

**Forest Code**

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**Biodiversity**

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**Terrestrial Surface & Water Quality and Carbon Sequestration**

- Nutrients & sediments in waterways
- Carbon sequestration from habitats
2nd Optimization Approach: Efficiency Frontiers

**Agriculture**
- Cattle ranching
- Sugar cane

- Economic return ($)

**Forest Code**

- Amount of habitat required (LRs + PPAs)
- Cost of Forest Code compliance ($)

**Biodiversity**

- # of Birds & Mammals in landscape

**Terrestrial Surface**

**Water Quality & Carbon Sequestration**

- Nutrients & sediments in waterways
- Carbon sequestration from habitats
Efficiency Frontier: Service Trade-offs

Opt for BD
Opt for WQ

Opt for BD
Opt for WQ

vs

Species (birds & mammals) vs Agricultural profit (in million USD)

N. reduction (in tons) vs Agricultural profit (in million USD)

- Only BD
- High BD
- Medium BD
- Low BD
- Only WQ
Efficiency Frontier: Improving Outcomes

Current Landscape

The graph shows the relationship between species (birds & mammals) and agricultural profit (in million USD) for different scenarios. The efficiency frontier indicates potential improvements in outcomes by balancing species diversity and profitability.
Efficiency Frontier: Improving Outcomes

- Gain >100 species
- 3x Reduction of nutrients in waterways

Maps showing the current and potential future states of agricultural profit and species richness.
Joint BD-WQ Planning at Different Scales

Property-level

[Graphs showing species and N reductions in relation to agricultural profit]

Legend:
- Unconstrained
- Landscape
- Property
Joint BD-WQ Planning at Different Scales

X  Property-level

Landscape-level

#Species (birds & mammals)

Agricultural profit (in million USD)

Unconstrained Landscape Property

Property-level

Landscape-level

Agricultural profit (in million USD)

N reductions (in tons)

Unconstrained Property
Designing Sustainable Landscapes

• **1 Billion new hectares** of agricultural land projected to sustain global demands for food, fodder, and fuel (Tilman et al. 2011)

• **Mitigation** is key mechanism to influence **environmental decision-making** (Madsen et al. 2011)

• Call for mitigation to **scale up**: move beyond site-specific to **landscape-level** (Hayes et al. 2014)

• Results indicate that landscape-level mitigation can provide **both business & conservation benefits**
  • Reduce costs to private landowners/developers
  • Enhance biodiversity
  • Provide additional carbon sequestration
  • Maintain water quality

• Need for mitigation to **broaden in scope**
  • Balance **both economic & environmental** trade-offs
  • Jointly plan for **both BD & ES** to prevent inadvertent losses
  • Proactively design **sustainable, multi-functional landscapes**
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