The State of the Science & Practice using Urban Trees as a Stormwater Control Measure

PRESENTED BY: DEEP ROOT GREEN INFRASTRUCTURE...Makers of Silva Cells

Peter MacDonagh PLA FASLA ISA RHS Al Key Owner
Director of Science & Design: Kestrel Design Group Deep Root Green Infrastructure LLC
Practice Professor: University of Minnesota New York, NY

May 5, 2016
Ohio SW Cleveland OH “The Forest City” 39.1”/Type 2/19% UTCC

POLL & Volumize & Luke & TSS Sizes & NP
INTRODUCTION

So You Want an Urban Forest that Cleans Water?

**DO This…..**

- Codify Minimum LOAM Soil VOLUMES FIRST >1000cf
- DIVERSIFY Species
- No Single Tree Genus >5%
- Set Minimum CANOPY TARGET >25% West of the Mississippi River with Deadline
- FIND & FILL GAPS with Trees
- Plant Lots of SMALL TREES with LARGE SOIL Volumes
- Monitor & Apply Responsive O&M

**Don’t Do This…..**

- Plant Trees in Small PITS
- Plant Trees in COMPACTED SOIL or SAND or STRUCTURAL SOIL
- Plant Lots of A FEW Species
- Plant Trees Only After COMPLAINTS
- Plant Tree Root Packages LOW
- Plant Trees As BEFORE
- Announce a MILLION Tree Planting Program Applying Above Steps
- Respond to Merchants Complaining about Trees BLOCKING Their SIGNS by Removing Trees

©Copyright The Kestrel Design Group, Inc. 2010
5 KEYS to a SUCCESSFUL URBAN FOREST

Become Part of Stormwater System

1. REQUIRE LARGE (2:1/>1,000 cf) SOIL VOLUMES
2. SPECIES DIVERSITY (UTC <5% GENUS)
3. DIRECT STORMWATER to TREES
4. SHOW STORMWATER VALUE of TREES
5. CALCULATE STORMWATER CREDITS for TREES

Trees Require Portion of Stormwater Budget
What’s So Great About Big Trees?

Stormwater Interception by Hackberries versus Age of Tree

150 Gal. Year 5

5000 Gal. Year 40

It takes up to 22 years for an urban tree to reach mature size and provide the most benefits - the same time it takes a student to finish college.

San Francisco: Coastal Redwoods 1972-2014
42 Years = 120+ feet
Soil Volume and Canopy Size?
Germany: Type 1A

Pride & Joy

A “Special Tree…..”
Spilled Diesel?
Hours of Idling Machines?
Concrete & Sheetrock Soil Amendments?
String Trimmer Bark Treatments?
Deep Trunk Immersion?
Once Yearly Watering?
Salt Spray Foliar Feedings?
&
Ran out of Money?

Actual conditions: Average street tree has access to between 0.9 m³ (32 ft³) to 1.8 m³ (64 ft³) of soil.

MSP MN: Honeylocust (Gleditsia triacanthos)
Zone 4, Type II Storms, 31” Annual Precipitation
Let’s End Magical Thinking about Trees*

A bracadabra!

Ta Da!

*Peter MacDonagh
The Kestrel Design Group

KEY #1: LARGE (>1,000 CF) ROOT SOIL VOLUME = 95% GOOD TREES

Walt Disney World Orlando FL
USDA Zone 9; Type III Storms; 51” Annual Precipitation
Kent et al 2003

  - Define Tree Success: Good, Fair, Poor, Dead
  - Relationships: Soil Vol & Tree Condition
  - Test Applicability: Soil Vol Recommendations

- GOOD CONDITION
  - 100% of Trees in 1,500 CF (Cubic Feet)
  - 95% of Trees in 1,000 CF
  - 84% of Trees in 500 CF
  - 65% of trees in 100 CF
What do Trees Need to Get Big? Will We Ever Know?
YES We Know Now!

Trees Need Large Volumes of Oxygenated Soil

“Ideal” Conditions

1 in the AIR: 2 in the GROUND
1,000 CF Per Tree

Minimum Soil Volume Standards
Research vs. Adopted

METASTUDY: RESEARCH RESULTS - Minimum Rootable Tree Soil Volumes based on Field Studies or Water or Nutrient Requirements vs ADOPTED POLICY STANDARDS - Minimum Tree Rootable Soil Volume Standards in North American Municipalities

KEY #2: SPECIES DIVERSITY (<5% UTC per GENUS)

What We Had & Lost
SuperTrees that Can Grow Anywhere?
BUT Can’t survive Monocultures

American Chestnut: Chestnut Blight (CB)
American Elm: DED Dutch Elm Disease
American Ash: EAB Emerald Ash Borer

Image to the right from the Forest History Society, Inc. at http://www.appalachianwoods.com/appalachianwoods/history_of_the_american_chestnut.htm

In the Late 1800s, American Elm made up 90% of the boulevard trees in Minneapolis
•1963: First Dutch Elm Disease Detected in Trees
•1977: 31,000 Elm Trees Removed
•1978: 20,000 Elm Trees Removed
•2004: 10,000 Elm Trees Removed
•2005-2015: 2,700 Elm Trees Removed Annually

Since 1977, 63,700 Elm trees have been removed in the boulevards of Minneapolis.
Minneapolis Chain of Lakes Correlative Study
MacDonagh 2014: Unpublished

53 Square Miles

Relationship of Tree Species Diversity and Water Quality

Dutch Elm Disease

Elm Canopy Loss
19 Square Miles
There is a correlation to loss of tree canopy and water clarity
Following the removal of Elm trees (during the late 1970s and early 1990s), there was a
marked decrease in water clarity depth in the Chain of Lakes, yet building development
stopped in 1953 throughout the contributing sub-watershed around Lake Calhoun.

![Relationship of Tree Species Diversity and Water Quality](image)

**Lake Calhoun Lake Clarity Depth Over Time in METERS**

- **Meters**
  - 0
  - 1
  - 2
  - 3
  - 4
  - 5
  - 6
- **Lake Clarity Depth (meters)**

**Data Collected from the Citizen Lake Monitoring Program for Lake Calhoun, Minnesota**

**Pollution Control Agency**

**Remedial Action**

1. **Wildlife Skyscrapers (Cormorant Platform) at Lake Harriet Beachpool**
2. **Minneapolis Creek Streambank Soil Engineering Stabilization approach**
3. **Mercy Holmes Neighborhood Rain Garden providing infrastructure to collect stormwater runoff from adjacent roofs and parking lot**
4. **Green roof at the Phillips Eco-Enterprise Center creating stormwater & wildlife infrastructure**
5. **Lake Nokomis Stormwater Wetlands: pre-sediment landscape improving stormwater and wildlife infrastructure design**
Relationship of Tree Species Diversity and Water Quality

Dutch Elm Disease & Emerald Ash Borer

Elm Canopy Loss

Potential Ash Canopy Loss

Luke...Failure to Irrigate
KEY #3: DIRECT STORMWATER TOWARDS TREES

Sheet Flow / Curb Cut

Porous Pavement

Pretreatment
Distribution
Overflow
Catch Basin

Pretreatment Distribution Overflow

Rain Leader

STANDARD EMERGENCY

Backflow preventers

STREET

BUILDING
Notions, Potions & Data

KEY #4: SHOW STORMWATER VALUE of TREES
Directly Connected Impervious Drainage Area (DCIA)
NCSU Research

- Pond liner
- Runoff from street directed via a catch basin & sump into distribution pipe into the Silva Cells (see A)
- Underdrains with upturned elbows slow water, denitrify, then direct runoff into the Wilmington’s MS4 (see B)
  
  Profile by Jonathan Page, NCSU Biological and Agricultural Engineering

NCSU Research

Water Quality Results

Silva Cells at Wilmington DARKER vs. Mean Traditional Bioretention Results From Peer Reviewed Literature LIGHTER
Significantly less bypass is expected at typical Silva Cell installations because:

1) Pond liner was used so no exfiltration was possible – for typical Silva Cell installations pond liner is NOT so exfiltration is possible.
2) Drainage area to these Silva Cell systems (1 tree per 0.1 acre) was significantly greater than typical installations.

NCSU Research
Percent of Runoff Treated

68% of the runoff was treated by the Ann St Silva Cell system.

NCSU Research
62% Peak Flow Reduction

Despite pond liner and large drainage area, mean peak flow decreased 62% from 0.13 cfs to 0.05 cfs.
KEY #5: CALCULATE STORMWATER CREDIT FOR TREES
Minnesota Stormwater Manual: Tree Chapter
http://stormwater.pca.state.mn.us/index.php/Trees

- Tree quality and planting
- Soil quality
- Minimum soil volume
- Techniques available to provide rootable soil under load bearing surfaces.
- Species list for tree SCMs
- Maintenance
- Inspection form
- Monitoring

Full ET credit for a mature tree is given IF 2 c.f. of soil is provided per 1 s.f. of canopy at Planting

Minnesota Stormwater Manual: Tree Chapter
Example Tree Credit Calculation Sample Scenario

- Watershed: 270’ long x 20’ wide sidewalk (0.12396 acres)
- Tree SCM: 266’ long x 16’ wide x 2.58’ deep
- Silva Cells with 9 large trees, 30’ oc

BMP Parameters
Continued on next screen

- AREA: 4256 s.f.
- DEPTH: 2.58 ft.
- 9 TREES
Chesapeake Bay Tree Credits: 2016
Upland Forest Conservation;
Individual Tree Planting;
Existing Tree Rescue

B3 (Minnesota Sustainable Building Guidelines) b3mn.org
2003; 2014
S.3 Soil Management
Min. Soil Volumes for Trees: Sm, Med, L

LA GS Jim U; Columbus; Cleveland
5 KEYS to a SUCCESSFUL URBAN FOREST

Become Part of Stormwater System

1. REQUIRE LARGE (2:1/>1,000 cf) SOIL VOLUMES
2. SPECIES DIVERSITY (UTC <5% GENUS)
3. DIRECT STORMWATER to TREES
4. SHOW STORMWATER VALUE of TREES
5. CALCULATE STORMWATER CREDITS for TREES

Trees Require Portion of Stormwater Budget

Case Studies: Trees for Stormwater Management

• Al Key, Owner Deep Root Green Infrastructure…Makers of the Silva Cell
• Christian Science Center; 9/11; Aurora; Queensway; Midwest; Uptown Normal; Ohio Expo Center
References


References


Assessing the Long-Term Impacts and Costs of Urban Tree Canopy Loss from Destructive Forest Pests and Diseases

David Sivyer, Richard Hauer, Ian Hanou
City of Milwaukee, UW-Stevens Point, Plan-it Geo

Introduction
This study investigated the retrospective effects of Dutch elm disease (Ophiostoma novo-ulmi) on the loss of tree canopy in Milwaukee, WI USA. An i-Tree Eco analysis along with economic modeling were used to quantify the effects of management practices (no control versus fair, good, or best management options). Results also were used to quantify the economic outcomes of emerald ash borer (Agrilus planipennis) and determine future management actions for this insect.

Objectives

- Determine the cumulative loss in benefits from over 100,000 elm removals due to Dutch elm disease (DED)
- Develop biometric models of the elm population (structural attributes, mortality, growth, and condition)
- Determine the low point in Milwaukee’s canopy from DED
- Discover how long it took the canopy cover to recover
- Quantify the NPV & B/C associated with various management scenarios used to slow elm loss from DED
- Understand what lessons can be applied to EAB management

Population Modeling

- Starting population in 1956 known (106,732 elms)
- Used mortality methods of Cannon and Worley (1976)
- Biometric models: Am. elm diameter (crown, height, etc.)
- i-Trees Eco used to model ecologic & econometric values

Results

- Storm water benefits were equal to DED management costs
- DED management costs money regardless of management
- Net present value (NPV) and benefit cost (B/C) were highest for best control, no control was the least desirable
- Results from EAB modeling consistent with DED modeling
- Net present value (NPV) and benefit cost (B/C) were highest for treatment, preemptive removal is least desirable for EAB
- Recovery from DED took ~ 50 years, the same result is expected for EAB if the treatment option is not used
- Milwaukee was unable to practice best DED management in 1960’s, science of a best control tactic was not yet developed
- Active management of EAB is being used to treat most all healthy ash trees with the goal to retain tree canopy cover

The cost to manage Dutch elm disease (DED) and the net present value and benefit cost of management options

The cost to manage emerald ash borer (EAB) and the net present value and benefit cost of management options

Loss of tree canopy from DED in Milwaukee

- Foregone Eco Benefits (1956-2013 in millions)
  - Stormwater
  - Air pollution
  - Energy savings
  - CO2 Seq.

Loss of tree canopy from DED in Milwaukee

- 1996

<table>
<thead>
<tr>
<th>Year</th>
<th>&quot;Actual&quot; Elm Pop.</th>
<th>No Control (18% Annual Mortality)</th>
<th>Fair Control (5% Annual Mortality)</th>
<th>Good Control (3.5% Annual Mortality)</th>
<th>Best Control (1.0% Annual Mortality)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1963</td>
<td>102,355</td>
<td>83,623</td>
<td>95,490</td>
<td>96,822</td>
<td>99,222</td>
</tr>
<tr>
<td>1969</td>
<td>50,634</td>
<td>26,311</td>
<td>67,875</td>
<td>75,172</td>
<td>88,852</td>
</tr>
<tr>
<td>1979</td>
<td>9,181</td>
<td>3,240</td>
<td>36,952</td>
<td>47,935</td>
<td>73,344</td>
</tr>
<tr>
<td>1986</td>
<td>4,994</td>
<td>748</td>
<td>24,142</td>
<td>34,983</td>
<td>64,128</td>
</tr>
<tr>
<td>1996</td>
<td>3,318</td>
<td>92</td>
<td>13,142</td>
<td>22,307</td>
<td>52,934</td>
</tr>
</tbody>
</table>

* Mortality modeling based on Cannon and Worley (1976)
Why Trees Matter:
Data Supported Evaluation of the Impact and Value of Community Trees

Lee Mueller, Davey Resource Group
August 30, 2016
Aesthetics
“Cutting down trees spoils the beauty of the landscape...”

Wildlife habitat
“There are few birds where there are no trees...”

Flood control
“We might have dangerous floods if we did not have trees...”
“The leaves of trees catch the rain and hold it...”
“...the moisture that should sink into the soil is carried away in the floods.”

Climate change
Without forests...“we have severe droughts every year.”
“We should have greater extremes of heat and cold if it were not for the trees and forests.”

National Tree Benefit Calculator

This 24 inch American elm provides overall benefits of $252 every year.

While some functional benefits of trees are well documented, others are difficult to quantify (e.g., human social and commercial benefits). These specific geography, climate, and interactions with human and infrastructures are highly variable and make precise calculations that much more difficult. Given these complexities, the results presented here should be considered initial approximations—a rough accounting—of the benefits produced by urban street-side plantings.

Benefits of trees do not account for the costs associated with trees' long-term care and maintenance.

If this tree is cared for and grows to 20 inches, it will provide $305 in annual benefits.
<table>
<thead>
<tr>
<th>Au Gres’ Tree Canopy Ecosystem Benefits</th>
<th>Annual Ecosystem Benefits</th>
</tr>
</thead>
<tbody>
<tr>
<td>Quantity</td>
<td>Value</td>
</tr>
<tr>
<td>Air: CO (carbon monoxide) removed</td>
<td>215 lbs. $3</td>
</tr>
<tr>
<td>Air: NO₂ (nitrogen dioxide) removed</td>
<td>93 lbs. $0</td>
</tr>
<tr>
<td>Air: O₃ (ozone) removed</td>
<td>19,940 lbs. $643</td>
</tr>
<tr>
<td>Air: SO₂ (sulfur dioxide) removed</td>
<td>3,200 lbs. $4</td>
</tr>
<tr>
<td>Air: particulate matter (dust, soot, etc.) removed</td>
<td>5,880 lbs. $340</td>
</tr>
<tr>
<td>Carbon sequestered</td>
<td>1,419 tons $51,338</td>
</tr>
<tr>
<td>Stormwater: reduction in runoff</td>
<td>40,751,777 gals. $87,066</td>
</tr>
<tr>
<td><strong>Total Annual Benefits</strong></td>
<td><strong>$139,394</strong></td>
</tr>
<tr>
<td>Current stored carbon *</td>
<td>49,566 tons $1,794,713</td>
</tr>
</tbody>
</table>

**EFFECTS OF STREET TREE SHADE ON ASPHALT CONCRETE PAVEMENT PERFORMANCE**

By E. Gregory McPherson and Jules Muchnick

Abstract. Forty-eight street segments were paired into 24 high- and low-shade pairs in Modesto, California, U.S. Field data were collected to calculate a Pavement Condition Index (PCI) and Tree Shade Index (TSI) for each segment. Statistical analyses found that greater PCI was associated with greater TSI, indicating that tree shade was partially responsible for reduced pavement fatigue cracking, rutting, showing, and other distresses. Using observed relations between PCI and TSI, an undrained test segment required 6.31 years with 30 years, while an identical one planted with 32

crape myrtles ( Lagerstroemia indica, 4.4 m [14 ft] crown diameter) required 3.88 years, and one with 36 Chinese holly ( Ilex cornuta, 1.7 m [5 ft] crown diameter) required 2.76 years. Shade from the large hollies was projected to save $7.53/m²
(S$84.9/k) over the 30-year period compared to the unshaded street.

Key Words: Avoided repaving costs; pavement distress; tree benefits; urban heat island.
Business District Streetscapes, Trees, and Consumer Response

Kathleen L. Wolf

A multiyear research program has investigated how consumers respond to the urban forest in central business districts of cities of various sizes. Trees positively affect judgments of visual quality but, more significantly, may influence other consumer responses and behaviors. Survey respondents from all regions of the United States favored trees in business districts, and this preference was further reflected in positive district perceptions, patronage behavior, and product pricing. An overview of the research is provided, with implications for the economics of local communities.

Keywords: urban forestry, retail, public, preference, perception, valuation

Central business districts are the retail and civic centers of many urban neighborhoods and smaller cities.

Consumer response to retail settings is

Trees in the city: Valuing street trees in Portland, Oregon

Geoffrey H. Donovan<sup>a</sup>, David T. Bury<sup>b</sup>

<sup>a</sup>Pacific Northwest Research Station, Portland Forestry Sciences Laboratory, P.O. Box 20390, Portland, OR 97220, United States

<sup>b</sup>Building and Fire Research Laboratory, National Institute of Standards and Technology, Gaithersburg, MD 20899, United States

ABSTRACT

We use a hedonic price model to simultaneously estimate the effects of street trees on the sales price and the time-on-market (TOM) of homes in Portland, Oregon. On average, street trees add $4,770 to sales price and reduce TOM by 1.27 days. In addition, we found that the benefits of street trees spill over to neighboring houses. Because the provision and maintenance of street trees is the responsibility of adjacent property owners, our results suggest that if the provision of street trees is left solely to homeowners, then there will be too few street trees from a societal perspective.

Published by Elsevier B.V.
Short Report

Urban trees and the risk of poor birth outcomes

Geoffrey H. Donovan 1,*, Yonne L. Michael 2, David T. Runy 3, Amy D. Sullivan 4, John M. Chase 5

1 USDA Forest Service, PNW Research Station, Portland, OR, USA
2 Oregon State University College of Public Health, Portland, OR, USA
3 University of North Carolina Chapel Hill, Chapel Hill, NC, USA
4 Environmental Protection Agency, Portland, OR, USA
5 Oregon State University College of Public Health, Portland, OR, USA

ARTICLE INFO

Article Info:
Received 11 August 2013
Resubmission received 29 October 2013
Accepted 7 November 2013
Available online 18 November 2013

Keywords:
Reproductive health
Smog for prenatally
Protest birth
Urban trees

ABSTRACT

This paper investigated whether greater tree canopy cover is associated with reduced risk of poor birth outcomes in Portland, Oregon. Residential addresses were geocoded and linked to high-resolution aerial imagery to calculate tree canopy cover in 50, 100, and 200 m buffers around each home in our sample (n=5650). Detailed data on maternal characteristics and additional neighborhood variables were obtained from birth certificates and tax records. We found that a 10% increase in tree canopy cover within 50 m of a home reduced the number of small for gestational age infants by 1.42 per 1000 births (95% CI 0.13–2.72). Results suggest that the natural environment may affect pregnancy outcomes and should be evaluated in future research.

Published by Elsevier Ltd.

The relationship between trees and human health: evidence from the spread of the emerald ash borer.

Donovan GH, Bulit DT, Michael YL, Richardson JP, Lightfoot AM, Gabriels D, Mar K

Abstract

BACKGROUND: Several recent studies have identified a relationship between the natural environment and improved health outcomes. However, for practical reasons, most have been observational, cross-sectional studies.

PURPOSE: A natural experiment, which provides stronger evidence of causality, was used to test whether a major change to the natural environment—the loss of 100 million trees to the emerald ash borer, an invasive forest pest—has influenced mortality related to cardiovascular and lower-respiratory diseases.

METHODS: Two fixed-effects regression models were used to estimate the relationship between emerald ash borer presence and county-level mortality from 1990 to 2007 in 15 U.S. states, while controlling for a wide range of demographic covariates. Data were collected from 1990 to 2007, and the analyses were conducted in 2011 and 2012.

RESULTS: There was an increase in mortality related to cardiovascular and lower-respiratory-tract illness in counties infested with the emerald ash borer. The magnitude of this effect was greater as infestation progressed and in counties with above-average median household income. Across the 15 states in the study area, the borer was associated with an additional 6113 deaths related to illness of the lower respiratory system, and 15,000 cardiovascular-related deaths.

CONCLUSIONS: Results suggest that loss of trees to the emerald ash borer increased mortality related to cardiovascular and lower-respiratory-tract illness. This finding adds to the growing evidence that the natural environment provides major public health benefits.

Published by Elsevier Inc.
### Total Annual Benefits, Net Benefits, and Costs for Public Trees

<table>
<thead>
<tr>
<th>Benefits</th>
<th>Total ($) Standard Error</th>
<th>$/tree Standard Error</th>
<th>$/capita Standard Error</th>
</tr>
</thead>
<tbody>
<tr>
<td>Energy</td>
<td>2,584,333 (±141,133)</td>
<td>41.27 (±29)</td>
<td>13.13 (±0.75)</td>
</tr>
<tr>
<td>CO2</td>
<td>296,472 (±14,226)</td>
<td>4.16 (±0.20)</td>
<td>1.32 (±0.07)</td>
</tr>
<tr>
<td>Air Quality</td>
<td>332,084 (±14,321)</td>
<td>5.34 (±0.20)</td>
<td>1.63 (±0.09)</td>
</tr>
<tr>
<td>Stormwater</td>
<td>2,133,171 (±18,326)</td>
<td>34.60 (±1.92)</td>
<td>11.01 (±0.61)</td>
</tr>
<tr>
<td>Aesthetic/Other</td>
<td>1,241,668 (±68,875)</td>
<td>20.14 (±1.12)</td>
<td>6.41 (±0.36)</td>
</tr>
<tr>
<td><strong>Total Benefits</strong></td>
<td>6,608,751 (±360,481)</td>
<td>105.41 (±5.85)</td>
<td>33.55 (±1.86)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Costs</th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Planting</td>
<td>218,369</td>
<td>3.54</td>
<td>1.13</td>
</tr>
<tr>
<td>Contract Pruning</td>
<td>622,408</td>
<td>10.10</td>
<td>3.20</td>
</tr>
<tr>
<td>Pest Management</td>
<td>16,519</td>
<td>0.27</td>
<td>0.09</td>
</tr>
<tr>
<td>Irrigation</td>
<td>19,683</td>
<td>0.32</td>
<td>0.10</td>
</tr>
<tr>
<td>Removal</td>
<td>904,014</td>
<td>8.17</td>
<td>2.60</td>
</tr>
<tr>
<td>Administration</td>
<td>64,994</td>
<td>1.16</td>
<td>0.34</td>
</tr>
<tr>
<td>Inspection/Service</td>
<td>96,760</td>
<td>1.62</td>
<td>0.51</td>
</tr>
<tr>
<td>Infrastructure Repairs</td>
<td>39,094</td>
<td>0.63</td>
<td>0.20</td>
</tr>
<tr>
<td>Litter Cleanup</td>
<td>199,797</td>
<td>3.74</td>
<td>1.03</td>
</tr>
<tr>
<td>Liability/Claims</td>
<td>0</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>Other Costs</td>
<td>19,970</td>
<td>0.32</td>
<td>0.10</td>
</tr>
<tr>
<td><strong>Total Costs</strong></td>
<td>1,904,582</td>
<td>29.57</td>
<td>9.32</td>
</tr>
</tbody>
</table>

| Net Benefits      | 4,594,169 (±360,481)     | 76.14 (±5.85)          | 24.23 (±1.86)            |
| Benefit-cost ratio| 1.60 (±0.25)             |                       |                          |