The Inclusion of Large-scale Tree Planting in a SIP

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Overview

1. Background
2. Feasibility
3. Conclusions

1. Background

- 1.1 Personal info
- 1.2 Foundation research
- 1.3 Canopy factors
- 1.4 Regulatory context

1.1 Personal

- DRG consulting urban forester since 2K
- Co-authored 2002 NYC study with Chris Luley (modelers: Nowak, Civerolo)
- Consultant to 2005 project funded by FS Urban and Community Forestry
  - www.treescleanair.org
  - Factsheets, studies, information
  - Feasibility study

Feasibility Study

- Emerged from research suggestions that something like 800K to 1M trees/year could be planted
- Questions
  - Is this even possible?
  - What would we have to know?
  - What would it cost?
- Group effort: lots of help

1.2 Foundation research I

- Number of studies demonstrate that manipulating urban canopy impacts peak ozone levels
  - Atlanta study **(Cardelino and Chameides, 1990)**
  - South Coast Basin study **(Taha, 1996)**
  - Northeast study **(Nowak et al, 2000)**
  - NYC study **(Luley and Bond, 2002)**
  - CA study **(Taha 2005)**
  - Birmingham study **(Donovan et al 2005)**

“Interactions of the effects of trees on meteorology, dry deposition, volatile organic compound (VOC) emissions, and anthropogenic emissions demonstrate that <u>trees can cause changes in dry deposition and meteorology, particularly air temperatures, wind fields, and boundary layer heights</u>, which, in turn, affect ozone concentrations.” (Nowak et al 2000)

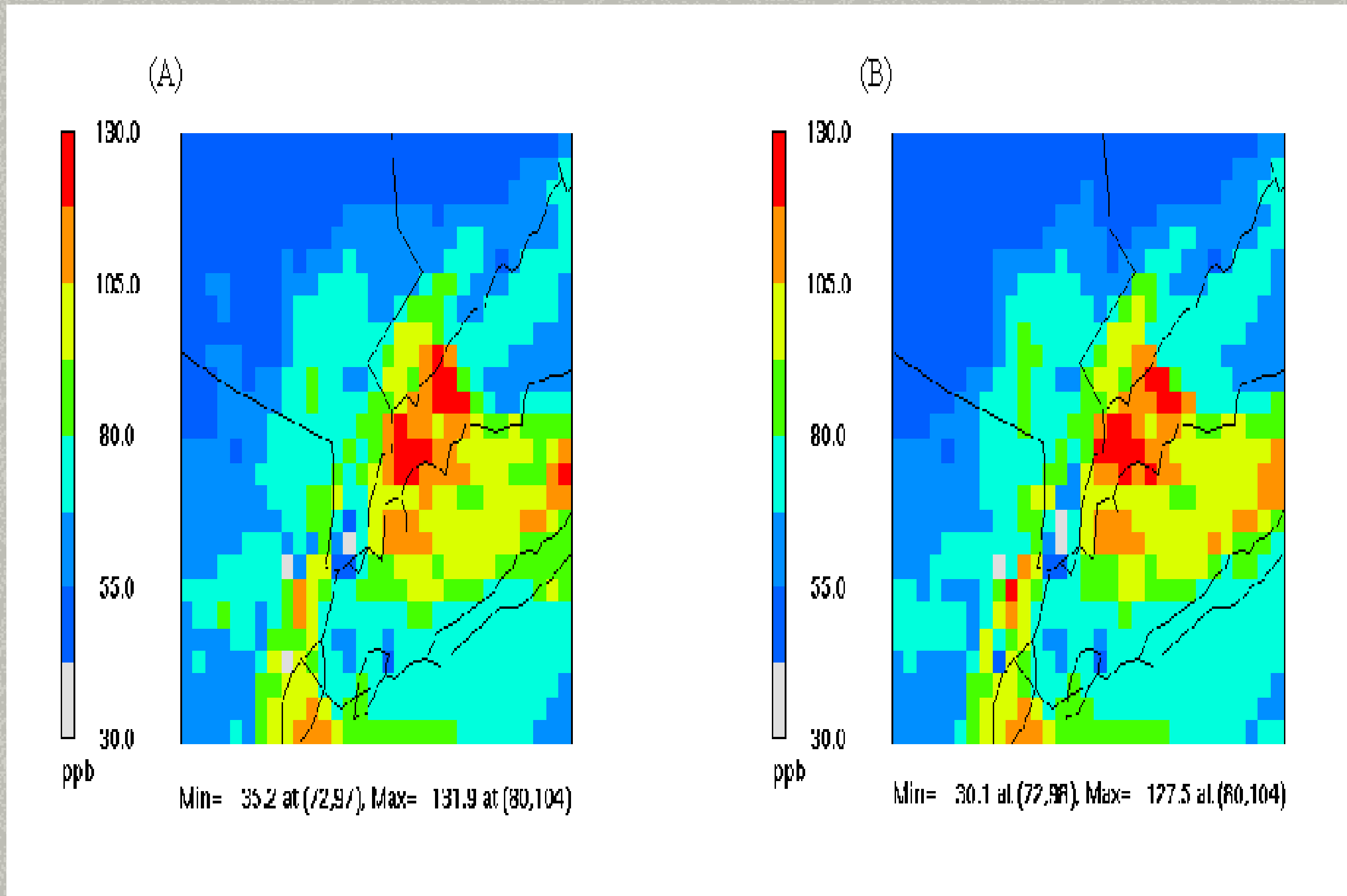


Figure 5 MODELS3-CMAQ results of July 15, 1995, with existing canopy (A) and realistic increased canopy (B), showing a reduction of daily ozone maximum by about 4 ppb. Source: Civerolo et al, 2001.

1.2 Foundation research II

- Urban vegetation impacts ozone levels by reducing temperature of “heat island”
- Trees are just one kind of vegetation, vegetation just one kind of strategy
  - Taha 2000
  - Hudischewskyj et al 2001
  - Taha 2005

“Ongoing research and field studies have shown how strategically planting shade trees and increasing the reflectivity of building and pavement surfaces can greatly reduce energy use for cooling, and prevent the formation of smog.

What is less obvious is the effect that these strategies can have on particular cities, given the numerous variables particular to different regions such as climate, topography, and population growth patterns.” (Gorsevski et al [1998])

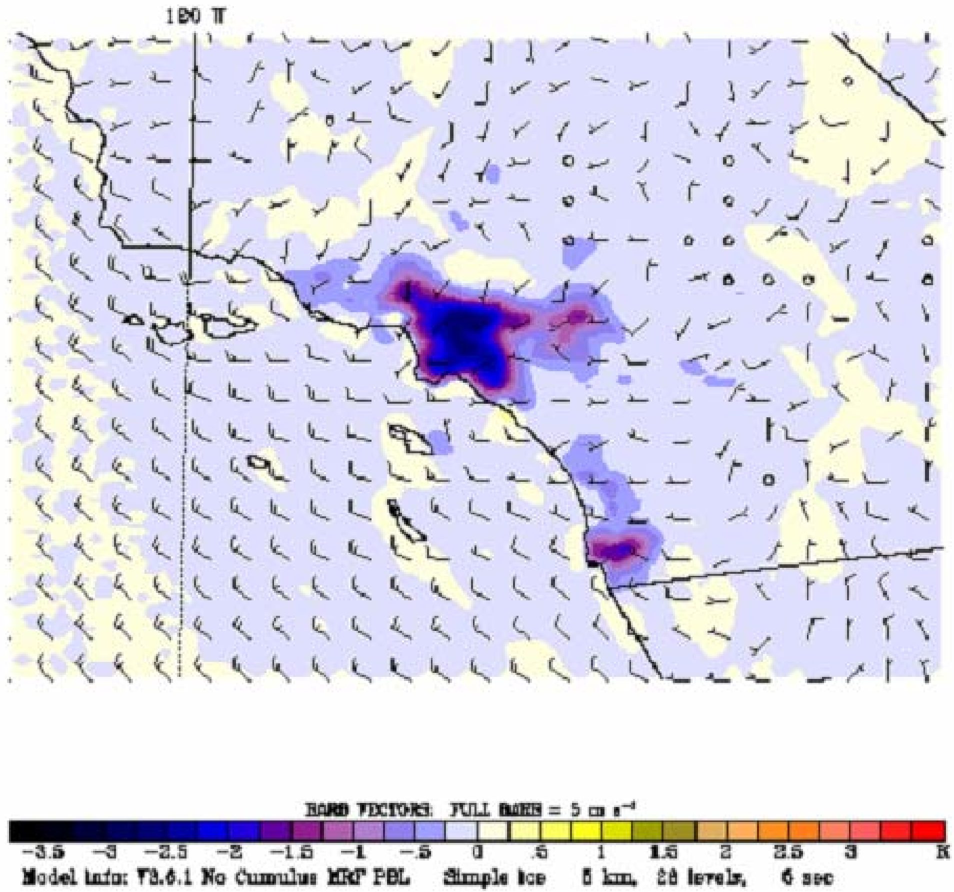


Figure ES-1. Change in air temperature in Southern California as a result of increased urban albedo and vegetative cover (1300 on August 4).

Source: Taha, Urban Surface Modification, Phase I (2005)

Twofer?

- Extensive tree benefit literature suggests trees not be just another pretty [green] face
- Quantified environmental, socio-economic and health benefits have been demonstrated
- Side benefits (non-ozone related) so great that we might consider tree planting a "criteria" strategy
- Larger frame: canopy manipulation

1.3 Canopy Change Factors

$$C_T = C_0 + C_G - C_L$$

where

C_T = future (0+T) canopy

C_0 = canopy at time zero

C_G = canopy growth

C_L = canopy loss

Canopy Growth Factors

$$C_G = C_{OldG} + C_{NewG}$$

where

$$C_{New} = C_{NatG} + C_{HumG}$$

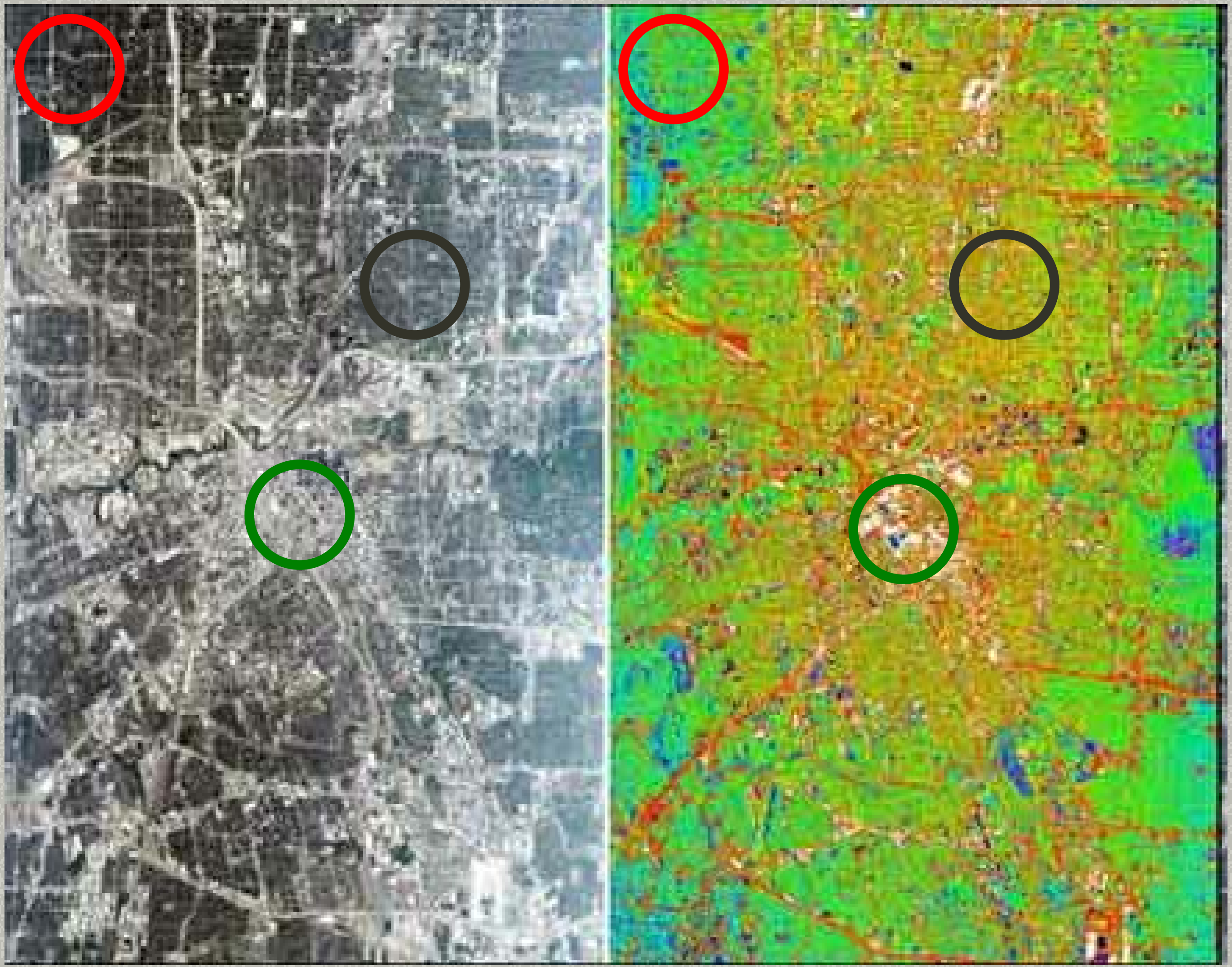
Canopy Loss Factors

$$C_L = C_{NatL} + C_{HumL}$$

- **NatL**
  - Normal biological processes
  - Disasters
- **HumL**
  - Normal urban forest processes
  - Development

SIP strategy

- In theory: any measure to
  - increase $\mathbf{C_G}$
  - decrease $\mathbf{C_L}$
- In practice: effective measures to
  - Increase tree planting, esp. in urban centers
  - Decrease tree loss, esp. in urban fringe



Source: NASA-Marshall Space Flight Center- Global Hydrology and Climate Center (EPA HIRI website)

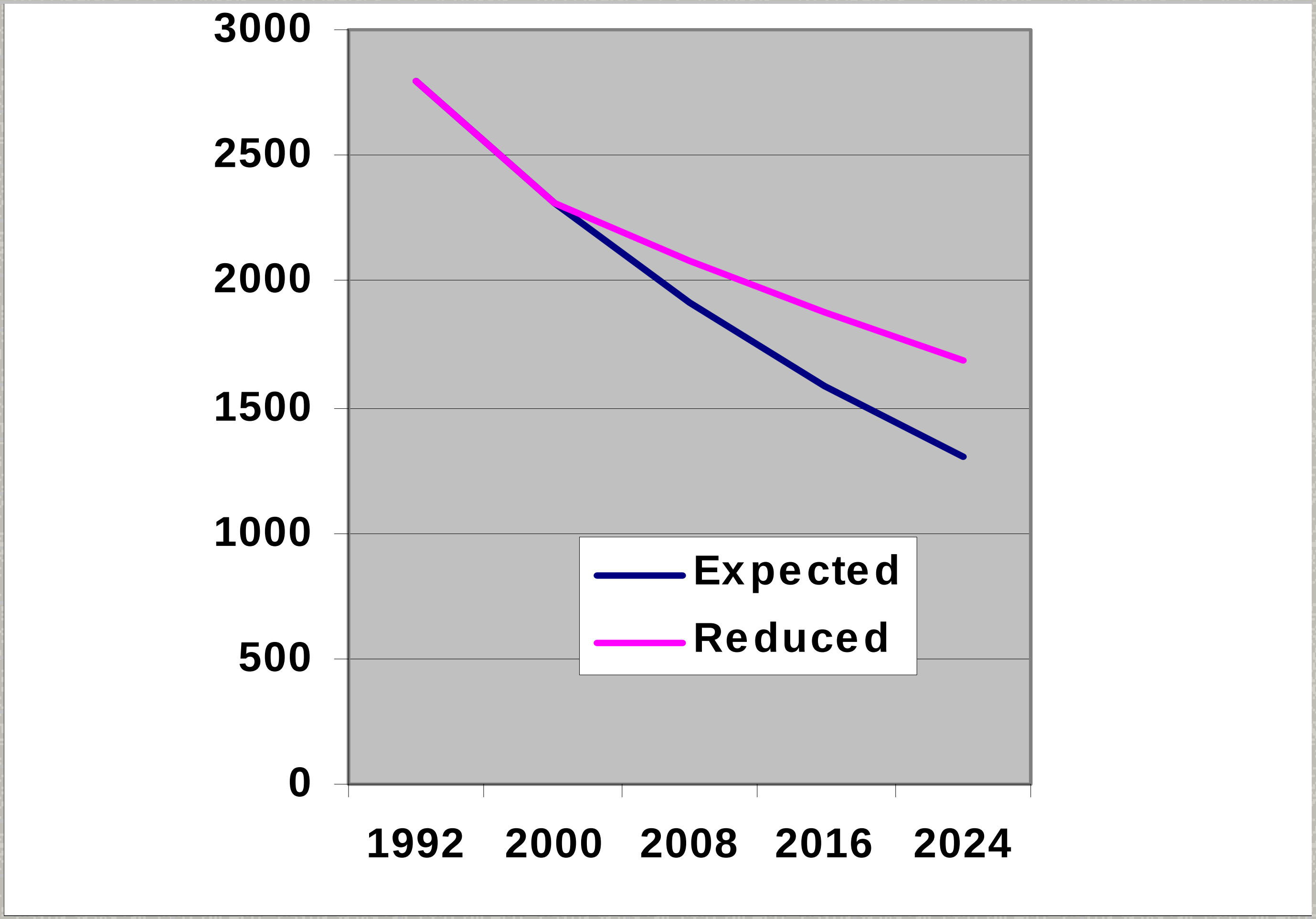
Feasibility study

- Only looked at
  - $\mathbf{C_{HumG}}$
  - Planned large-scale
- Contracted deliverable
- Need companion study: how to reduce $\mathbf{C_{HumL}}$

Canopy numbers

- Many factors poorly quantified for urban forest, if at all, e.g.
  - Current canopy
  - Trees being planted
  - Canopy loss
- Spatial distribution of gain and loss important as well
- If historical trend is known, could include reduction of net loss

Houston UFORE report data



Reduce rate to 10%/8yr, difference of 382 mi2

1.4 Regulatory context

- 15-yr interaction between researchers and EPA
- Two recent guidance documents make inclusion of tree planting much easier
  - Incorporating emerging and voluntary measures (September 2004)
  - Incorporating bundled measures (July 2005)
  - Both specifically include tree planting

Tree canopy/urban forestry	ozone	Reduces CO2 emissions, reduces energy usage, decreases storm water runoff, improves community livability and walkability.	Area-wide comprehensive tree planting. Strategic planting around homes and buildings directly cools the interior, decreasing air conditioning cost and peak energy demand.

Source: EPA, "Bundled" (2005), Appendix C of possible inclusions

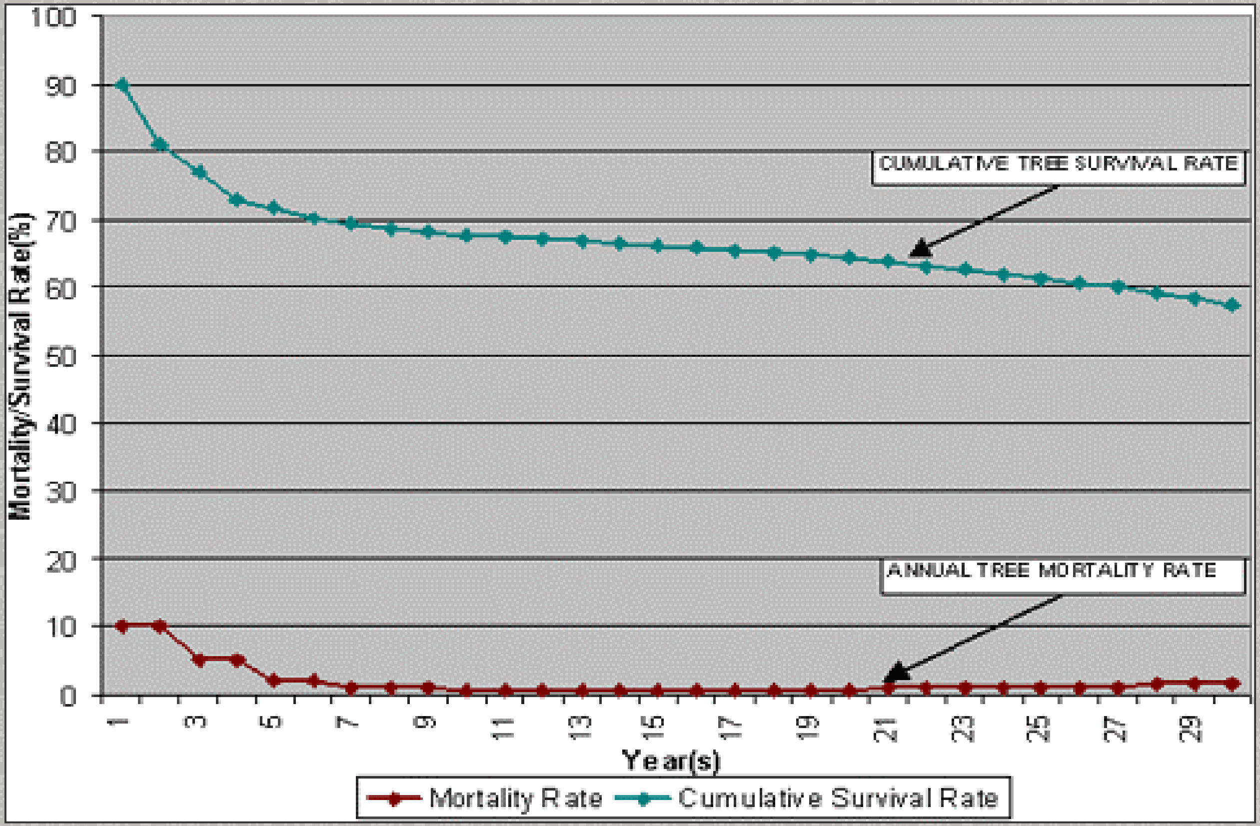
2. Feasibility

- Mortality
- Species
- Cost
- Site

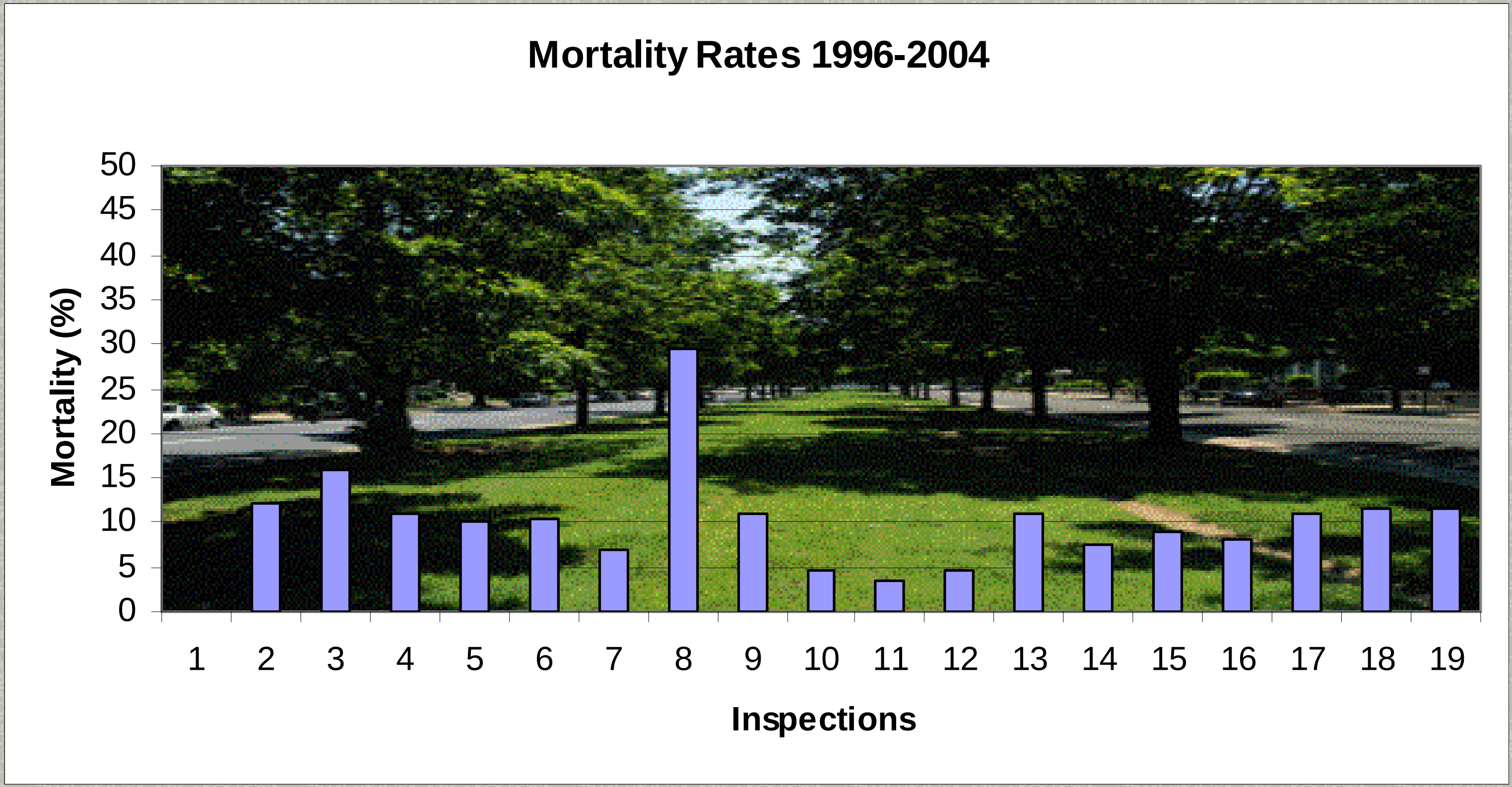
- Stock
- Planting
- Labor
- Verification

2.1 Mortality

- The basic argument
  - Modeling has shown that tree canopy can reduce pollution formation, as well as bring other air quality benefits
  - The benefits at a given future point (say, 30 years from present) depend on the projected size of the urban tree canopy
  - The projected canopy size relies on assumptions of growth and mortality
  - Large-scale planting can significantly affect future canopy size
  - Compliance within this component of a SIP will depend on the accuracy of the canopy projection



Source: http://usage.smud.org/treebenefit/data/mortalitygraph.asp, accessed October 2005



6-month mortality rate average 10.5% (SE 5.7%)

Source: Reworked from data in SMUD 2004

Mortality implications

- Projections of air quality benefits from urban forestry programs are very sensitive to tree survival rates (McPherson and Simpson 1999).
- If young tree mortality is not taken into account:
  - Canopy projections will be overly optimistic
  - Anticipated levels of air quality benefits too high.

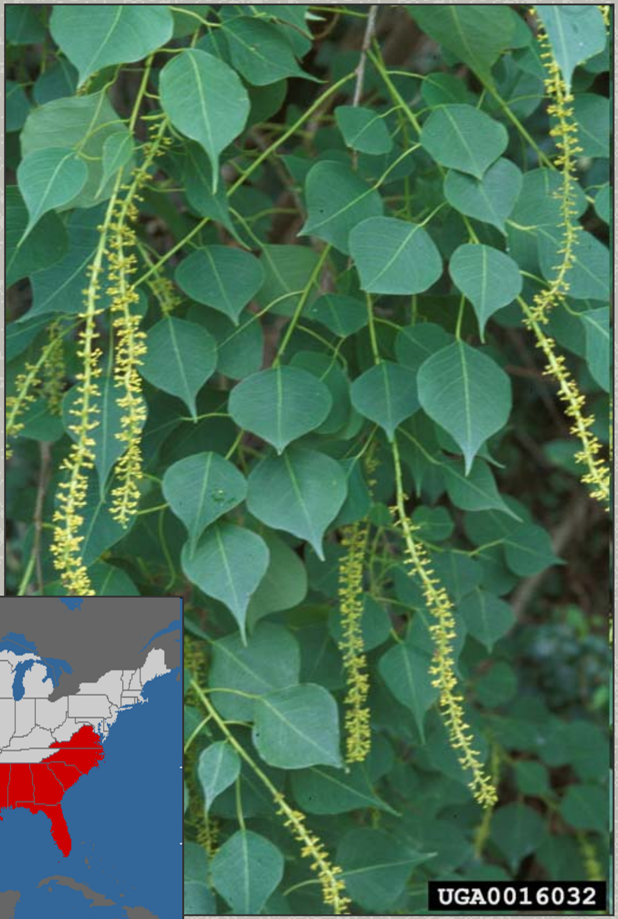
Establishment Period (approximately 1-4 years after planting)		
Annual Mortality Rate		Factors for Selecting Rate
High	7-9%	Hot and dry climate, untrained volunteer planting, unmonitored planting, unsuitable or low-quality stock, high stress planting sites, lack of post-planting care, no community involvement
Average	5-7%	
Low	3-5%	Temperate and moist climate, trained volunteers, monitoring of planting, high-quality stock, low-stress planting sites, post-planting care, community involvement

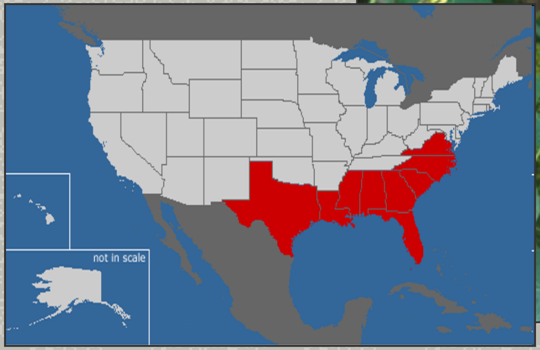
Recommendations

- Determine the needed number of trees using species-specific growth equations.
- Decide on the stock, planting methods and personnel, and sites.
- Select suitable mortality rates for the project, and calculate its effect on target number.
- **Ensure that enough additional trees will be planted to supply the desired target canopy.**

2.2 Species

- Species:site match
- Species diversity
- Invasiveness
- **VOC emitters**



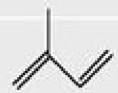
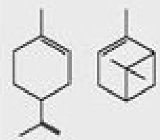
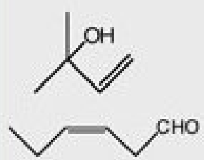
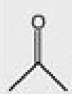


http://cswgcin.nbii.org/issues/invasives/galveston.html

VOC emitters

- More VOCS in presence of NOX and sunlight → more ozone *ceteris paribus*.
- Some tree genera produce much higher amounts of VOCs—adaptive defense.
- High VOC emitters include oaks, eucalyptus, sweetgum, poplars, spruces, and willows (Geron et al, 1994).

The Major Biogenic VOCs

Species	Chemical Structure	Primary Natural Sources	Annual Global Emission ($x10^{12}$ g C)	Reactivity (atmospheric lifetime in days)
Methane	CH_4	Wetlands, rice paddies	319-412	4000
Isoprene		Plants	175-503	0.2
Monoterpenes		Plants	127-480	0.1-0.2
Ethylene	$H_2C{=}CH_2$	Plants, soils, oceans	8-25	1.9
Other reactive VOCs		Plants	~260	<1
Other less reactive VOCs	 CH_3OH	Plants	~260	>1

Source: http://www.rfall.net/Why_VOCs.html (based on Fall 1999)

Test case: oaks

- Species variation within genus (Geron et al, 1994, Kesselmeier/Staudt 1998)
- Problematic in rural forest (Wiedinmyer et al 2005)—15% of Houston area forest!
- Long-lived, indigenous, drought-tolerant oaks have the potential to cool the urban environment much longer than other species.
- Uncertain how costs of higher VOC production would balance with:
  - Lower temperature
  - Higher survivability
  - Lower maintenance

Recommendations

- Develop careful species lists for soil types in target region
- Maintain species diversity, critical to overall success of urban forest
- Avoid known invasive species
- **Avoid blanket condemnation of high VOC genera: model on regional level, or set overall limit such as 20%**

2.3 Site

- Availability
- Location
- Approach

Availability

- Remote sensing
  - Techniques developed at USDA FS Research Unit in Syracuse, NY
  - DOQs (or equivalent), NLCDs
  - Used in NYC study to estimate plantable space
- Finer scale
  - Approach from ground
  - Need local knowledge: ownership, actual availability, soil traits, etc.
  - A lot of work!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Location

- Environmental benefit
  - “Where would the first tree go?”
  - Depends on what you want the first tree to do
    - **Carbon: anywhere in the domain**
    - **PM10: downwind, close to source**
    - **Ozone: in hottest area?**
- Environmental justice
  - Distribution of cooling and side benefits across population
  - Concern of EPA among others
  - Means using most challenging sites

Source:
http://www.irvington.net/Redevelopment/Brownfield%20Development%20Area.gif

Approach

- Top-down
  - Better for larger planting sites, e.g.
    - Vacant or abandoned land
    - Parks of all sizes and jurisdictions
    - Commercial landscapes
- Bottom-up
  - Better for smaller planting sites
  - Volunteer organizations have experience
  - Important side benefits (e.g., post-planting care)

Recommendations

- Use both top-down and bottom-up approaches
- Replace site analysis with targeted species lists
- Start with large, public, good-quality sites
- Plan for higher cost on inner-city sites

2.4 Cost

- First question for many people, yet appears uninvestigated
- Few available and applicable data
- Elected to cover two scenarios
  - Actual costs
  - Estimated costs

Actual costs

- Intertwined elements, e.g.
  - Stock size and labor
  - Planting site and stock size
  - Site and post-planting maintenance
- Substantial variation at local level
  - Stock
  - Labor
- Indirect costs usually unreported

Estimated costs

- Great range
- More uniformity in ratio of stock costs to program costs
  - Can use national stock cost averages
  - Ratio provides reliable estimate range
- Range: $25-100M per 1M trees
  - Houston: $90M for 1M trees (extrapolated)

Stock Type	Non-stock Cost Factor	Approximate 2005 Range of Stock Cost/Tree	Range of Non-stock Cost/Tree	Range of Total Cost per Planted Tree
Seedling	2-4 times stock cost	$0.15 - $0.40	$0.30 - $1.60	$0.45 - $2
1-yr plant	2-4 times stock cost	$2 - $10	$4 - $40	$6 - $50
2-yr liner/whip	2-4 times stock cost	$8 - $35	$16 - $140	$24 - $175
1-1.5” BR	1-3 times stock cost	$12 - $35	$12 - $105	$24 - $140
1” container	1-3 times stock cost	$25 - $50	$25 - $100	$50 - $150

SIP Tree-Planting Cost Estimator

Step 1: SET PROJECT INPUTS

Location	
Trees/Year Wanted	500,000
Est. Survival Rate	50%
Program Length (yrs)	2
Trees per Year	1,000,000
Total Trees	2,000,000

Hyperlinks like this take you to a detail worksheet

Step 2: SET SCENARIOS

	1	2	3	4
Seedlings	0%	10%	20%	100%
Liners	0%	30%	60%	0%
Bare Roots	0%	30%	10%	0%
Containers	50%	30%	10%	0%
B&B	50%	0%	0%	0%

These scenarios can be altered to suit local conditions, capabilities and interests. Be sure changes add up to 100%

Step 3: SET CALCULATION

Program cost relation to stock cost	Actual estimates

You can estimate program costs separately or as a multiple of stock costs using this pull-

OUTPUTS

	Scenarios 1	2	3	4
DIRECT COSTS				
Materials	$ 378,580,000	$ 138,028,000	$ 72,476,000	$ 4,060,000
Labor	$ -	$ -	$ -	$ -
Equipment	$ -	$ -	$ -	$ -
Other	$ -	$ -	$ -	$ -
INDIRECT COSTS				
Materials	$ -	$ -	$ -	$ -
Labor	$ -	$ -	$ -	$ -
Equipment	$ -	$ -	$ -	$ -
Other	$ -	$ -	$ -	$ -
TOTALS				
Total Direct Cost	$ 378,580,000	$ 138,028,000	$ 72,476,000	$ 4,060,000
Total Indirect Cost	$ -	$ -	$ -	$ -
Cost/Tree	$ 189	$ 69	$ 36	$ 2
Total Cost/Year	$ 189,290,000	$ 69,014,000	$ 36,238,000	$ 2,030,000
Total Program Cost	$ 378,580,000	$ 138,028,000	$ 72,476,000	$ 4,060,000

These numbers are calculated automatically using data from the project inputs, the scenarios, and the relevant

http://treescleanair.org/policymakers/factsheets/CostEstimator.xls

SIP Tree-Planting Cost Estimator

Step 1: SET PROJECT INPUTS

Location	
Trees/Year Wanted	500,000
Est. Survival Rate	50%
Program Length (yrs)	2
Trees per Year	1,000,000
Total Trees	2,000,000

Hyperlinks like this take you to a detail worksheet

Step 2: SET SCENARIOS

	1	2	3	4
Seedlings	0%	10%	20%	100%
Liners	0%	30%	60%	0%
Bare Roots	0%	30%	10%	0%
Containers	50%	30%	10%	0%
B&B	50%	0%	0%	0%

These scenarios can be altered to suit local conditions, capabilities and interests. Be sure changes add up to 100%

Step 3: SET CALCULATION

Program cost relation to stock cost	2

You can estimate program costs separately or as a multiple of stock costs using this pull-

OUTPUTS

		Scenarios 1	Scenarios 2	Scenarios 3	Scenarios 4
DIRECT COSTS					
	Materials	[redacted]			
	Labor				
	Equipment				
	Other				
INDIRECT COSTS					
	Materials	[redacted]			
	Labor				
	Equipment				
	Other				
TOTALS					
	Total Stock Cost	$ 125,000,000	$ 134,448,000	$ 68,896,000	$ 480,000
	Total Program Cost	$ 250,000,000	$ 268,896,000	$ 137,792,000	$ 960,000
	Cost/Tree	$ 188	$ 202	$ 103	$ 1
	Total Cost/Year	$ 187,500,000	$ 201,672,000	$ 103,344,000	$ 720,000
	Total Program Cost	$ 375,000,000	$ 403,344,000	$ 206,688,000	$ 1,440,000

These numbers are calculated automatically using data from the project inputs, the scenarios, and the relevant

Conclusions

- Serious but not insurmountable practical implications of trees-for-ozone policy
- As policy work proceeds, practical planning needs to keep step
- Minimum 3 years to ramp up